INTERIM FINAL FEASIBILITY STUDY APPENDIX E ENVIRONMENTAL TECHNICAL REPORTS NAB LITTLE CREEK VA

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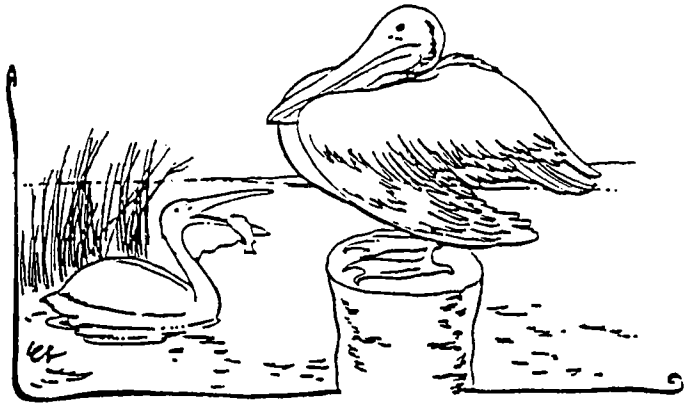
Interim Final Feasibility Study Appendix E – Environmental Technical Reports

ELIZABETH RIVER BASIN, VIRGINIA

ENVIRONMENTAL RESTORATION



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APPENDIX E

Environmental Technical Reports

APPENDIX E
ENVIRONMENTAL TECHNICAL REPORTS

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ATTACHMENTS

ATTACHMENT A

BENTHIC INDEX OF BIOTIC INTEGRITY (BIBI) INVESTIGATION

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BENTHIC BIOLOGICAL MONITORING PROGRAM OF THE ELIZABETH RIVER WATERSHED (1999)

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EXECUTIVE SUMMARY

A study of the macrobenthic communities of the Elizabeth River watershed was conducted in summer 1999. The three objectives of the Benthic Biological Monitoring Program of the Elizabeth River watershed are: (1) To characterize the health of regional areas of the tidal waters of the Elizabeth River watershed Chesapeake Bay as indicated by the structure of the benthic communities. These characterizations are based upon application of benthic restoration goals and the Benthic Index of Biotic Integrity (BIBI) developed for the Chesapeake Bay to five primary strata - the Mainstem of the river, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch. Within each stratum samples were randomly allocated in a probability-based sampling design. A probability-based sampling design allows calculation of confidence intervals around estimates of condition of the benthic communities. (2) To conduct trend analyses on long-term data at 14 fixed-point stations to relate temporal trends in the benthic communities to changes in water and/or sediment quality. Trend analyses will be updated annually as new data are available. (3) To produce an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality. In addition in the 1999, sampling event two additional strata were sampled for benthic community condition: (1) Scuffletown Creek, a proposed location for sediment contaminant remediation and (2) an additional nearby small creek system - the Jones and Gilligan Creek complex.

The condition of the seven strata was compared to the results for all Virginia tidal waters for 1999 based upon the random sampling of 100 sites as part of the on-going Virginia Benthic Monitoring Program. In 1999 Virginia tidal waters averaged 30% degraded benthic bottom. All seven strata for the Elizabeth River were higher than this value - 52% for the Mainstem of the River, 64% for the Lafayette River, 64% for the Eastern Branch, 72% for the Western Branch and 92% for the Southern Branch. Scuffletown Creek and Jones-Gilligan Creek both averaged 76% area failing the Benthic Restoration Goals. In general for all Elizabeth River strata, species diversity and biomass were below reference condition levels while abundance values were within reference condition levels. Community composition was unbalanced with levels of pollution indicative species above and levels of pollution sensitive species below reference conditions. The only exceptions to these patterns was the Mainstem of the river where biomass and levels of pollution sensitive species were within reference condition levels.

INTRODUCTION

A study of the macrobenthic communities of the Elizabeth River watershed was conducted in summer 1999. The three objectives of the Benthic Biological Monitoring Program of the Elizabeth River watershed are: (1) To characterize the health of regional areas of the tidal waters of the Elizabeth River watershed Chesapeake Bay as indicated by the structure of the benthic communities. These characterizations are based upon application of benthic restoration goals and the Benthic Index of Biotic Integrity (BIBI) developed for the Chesapeake Bay to five primary strata - the Mainstem of the River, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch. Within each stratum samples are randomly allocated in a probability-based sampling design. A probability-based sampling design allows calculation of confidence intervals around estimates of condition of the benthic communities. (2) To conduct trend analyses on long-term data at 14 fixed-point stations to relate temporal trends in the benthic communities to changes in water and/or sediment quality. Trend analyses will be updated annually as new data are available. (3) To produce an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality. In addition in the 1999, sampling event two additional strata were sampled for benthic community condition: (1) Scuffletown Creek, a proposed location for sediment contaminant remediation and (2) an additional nearby small creek system - the Jones and Gilligan Creek complex.

The macrbenthic communities of the Elizabeth River have been studied since the 1969 sampling of Boesch (1973) with three stations in the Mainstem of the river. Other important studies were limited to the Southern Branch of the river including seasonal sampling at 10 sites in 1977-1978 (Hawthorne and Dauer 1983), seasonal sampling at the same 10 sites a decade later in 1987-1988 by Hunley (1993), the establishment of two long-term monitoring stations in 1989 as part of the Virginia Chesapeake Bay Benthic Monitoring Program (Dauer et al. 1999) and summarizations of the two Southern Branch long-term monitoring stations (Dauer 1993, Dauer et al. 1993).

RATIONALE

Benthic invertebrates are used extensively as indicators of estuarine environmental status and trends because numerous studies have demonstrated that benthos respond predictably to many kinds of natural and anthropogenic stress (Pearson and Rosenberg 1978; Dauer 1993; Tapp et al. 1993; Wilson and Jeffrey 1994). Many characteristics of benthic assemblages make them useful indicators (Bilyard 1987), the most important of which are related to their exposure to stress and the diversity of their response. Exposure to hypoxia is typically greatest in near-bottom waters and anthropogenic contaminants often accumulate in sediments where benthos live. Benthic organisms generally have limited mobility and cannot avoid these adverse conditions. This immobility is advantageous in environmental assessments because, unlike most pelagic fauna, benthic assemblages reflect local environmental conditions (Gray 1979). The structure of benthic assemblages responds to many kinds of stress because these assemblages typically include organisms with a wide range of physiological tolerances, life history strategies,

feeding modes, and trophic interactions (Pearson and Rosenberg 1978; Rhoads et al. 1978; Boesch and Rosenberg 1981). Recently benthic community condition in the Chesapeake Bay has been related to water quality, sediment quality, nutrient loads, and land use patterns (Dauer et al. 2000).

METHODS

A glossary of selected terms used in this report is found on page 40.

Strata Sampled

The Elizabeth River watershed was divided into five primary strata - the Mainstem of the river, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch (Fig. 1). In addition two small creeks of the Southern Branch of the river were also sampled as part of a sediment contaminant remediation effort - Scuffletown Creek and Jones-Gilligan Creek.

Probability-based sampling

Sampling design and methodologies for probability-based sampling are based upon procedures developed by EPA's Environmental Monitoring and Assessment Program (EMAP, Weisberg et al. 1993) and allow unbiased comparisons of conditions between strata.

Within each probability-based stratum, 25 random locations were sampled using a 0.04 m^2 Young grab. The minimum acceptable depth of penetration of the grab was 7 cm. At each station one grab sample was taken for macrobenthic community analysis and a second grab sample for sediment particle size analysis and the determination of total volatile solids. A 50 g subsample of the surface sediment was taken for sediment analysis. Salinity, temperature and dissolved oxygen were measured at the bottom and water depth was recorded.

Probability-Based Estimation of Degradation

Areal estimates of degradation of benthic community condition within a stratum can be made because all locations in each stratum are randomly selected. The estimate of the proportion of a stratum failing the Benthic Restoration Goals developed for Chesapeake Bay (Ranasinghe et al. 1994; updated in Weisberg et al. 1997) is the proportion of the 25 samples with an B-IBI value of less than 3.00. The process produces a binomial distribution: the percentage of the stratum attaining goals versus the percentage not attaining the goals. With a binomial distribution the 95% confidence limits for these percentages can be calculated as:

$$95\%\ \text{Confidence Limit} = p \pm 1.96\ (\text{SQRT}(pq/N))$$

where p = percentage attaining goal, q = percentage not attaining goal and N = number of samples.

For each stratum, 50 random points were selected using the GIS system of Versar, Inc. Decimal degree reference coordinates were used with a precision of 0.000001 degrees (approximately 1 meter) which is a smaller distance than the accuracy of positioning; therefore, no area of a stratum is excluded from sampling and every point within a stratum has a chance of being sampled. In the field the first 25 acceptable sites are sampled. Sites may be rejected because of inaccessibility by boat, inadequate water depth or inability of the grab to obtain an adequate sample (e.g., on hard bottoms).

Fixed-Point Station sampling

Fourteen fixed point stations were established for long-term trend analysis (Fig. 2). All field collection procedures were the same as for probability based sampling except that three replicate Young grab sample were collected for macrobenthic community analysis.

Laboratory Analysis

Each replicate was sieved on a 0.5 mm screen, relaxed in dilute isopropyl alcohol and preserved with a buffered formalin-rose bengal solution. In the laboratory each replicate was sorted and all the individuals identified to the lowest possible taxon and enumerated. Biomass was estimated for each taxon as ash-free dry weight (AFDW) by drying to constant weight at 60 °C and ashing at 550 °C for four hours. Biomass was expressed as the difference between the dry and ashed weight.

Particle-size analysis was conducted using the techniques of Folk (1974). Each sediment sample is first separated into a sand fraction (> 63 μm) and a silt-clay fraction (< 63 μm). The sand fraction was dry sieved and the silt-clay fraction quantified by pipette analysis. For random stations, only the percent sand and percent silt-clay fraction were estimated. For the fixed-point stations particle-size distribution parameters were determined by the graphic and moment measures methods of Folk (1974). Total volatile solids of the sediment was estimated by the loss upon ignition method as described above and presented as percentage of the wight of the sediment.

Benthic Index of Biotic Integrity

B-IBI and Benthic Community Status Designations

The B-IBI is a multiple-metric index developed to identify the degree to which a benthic community meets the Chesapeake Bay Program's Benthic Community Restoration Goals (Ranasinghe et al. 1994; updated in Weisberg et al. 1997). The B-IBI provides a means for comparing relative condition of benthic invertebrate communities across habitat types. It also provides a validated mechanism for integrating several benthic community attributes indicative of community health into a single number that measures overall benthic community condition.

The B-IBI is scaled from 1 to 5, and sites with values of 3 or more are considered to meet the Restoration Goals. The index is calculated by scoring each of several attributes as either 5, 3, or 1 depending on whether the value of the attribute at a site approximates, deviates slightly from, or deviates strongly from the values found at reference sites in similar habitats, and then averaging these scores across attributes. The criteria for assigning these scores are numeric and dependent on habitat type. Application of the index is limited to a summer index period from July 15th through September 30th.

Benthic community condition was classified into four levels based on the B-IBI. Values less than 2 were classified as **severely degraded**; values form 2.0 to 2.6 were classified as **degraded**; values greater than 2.6 but less than 3.0 were classified as **marginal**; and values of 3.0 or more were classified as **meeting the goal.** Values in the marginal category do not meet the Restoration Goals, but they differ from the goals within the range of measurement error typically recorded between replicate samples. These categories are used in annual characterizations of the condition of the benthos in the Chesapeake Bay (Ranasinghe et al. 1994; Dauer et al. 1998a, 1998b; Ranasinghe et al. 1998).

Further Information concerning the B-IBI

The analytical approach used to develop the B-IBI was similar to the one Karr et al. (1986) used to develop comparable indices for freshwater fish communities. Selection of benthic community metrics and metric scoring thresholds were habitat-dependent but by using categorical scoring comparisons between habitat types were possible. A six-step procedure was used to develop the index: (1) acquiring and standardizing data sets from a number of monitoring programs, (2) temporally and spatially stratifying data sets to identify seasons and habitat types, (3) identifying reference sites, (4) selecting benthic community metrics, (5) selecting metric thresholds for scoring, and (6) validating the index with an independent data set (Weisberg et al. 1997). The B-IBI developed for Chesapeake Bay is based upon subtidal, unvegetated, infaunal macrobenthic communities. Hard-bottom communities, e.g., oyster beds, were not sampled because the sampling gears could not obtain adequate samples to characterize the associated infaunal communities. Infaunal communities associated with submerged aquatic vegetation (SAV) were not avoided, but were rarely sampled due to the limited spatial extent of SAV in Chesapeake Bay.

Only macrobenthic data sets based on processing with a sieve of 0.5 mm mesh aperture and identified to the lowest possible taxonomic level were used. A data set of over 2,000 samples collected from 1984 through 1994 was used to develop, calibrate and validate the index (see Table 1 in Weisberg et al. 1997). Because of inherent temporal sampling limitations in some of the data sets, only data from the period of July 15 through September 30 were used to develop the index. A multivariate cluster analysis of the biological data was performed to define habitat types. Salinity and sediment type were the two important factors defining habitat types and seven habitats were identified - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud habitats (see Table

5 in Weisberg et al. 1997).

Reference sites were selected as those sites which met all three of the following criteria: no sediment contaminant exceeded Long et al.'s (1995) effects range-median (ER-M) concentration, total organic content of the sediment was less than 2%, and bottom dissolved oxygen concentration was consistently high.

A total of 11 metrics representing measures of species diversity, community abundance and biomass, species composition, depth distribution within the sediment, and trophic composition were used to create the index (see Table 2 in Weisberg et al. 1997). The habitat-specific metrics were scored and combined into a single value of the B-IBI. Thresholds for the selected metrics were based on the distribution of values for the metric at the reference sites. Data used for validation were collected between 1992 and 1994 and were independent of data used to develop the index. The B-IBI classified 93% of the validation sites correctly (Weisberg et al. 1997).

In tables presenting B-IBI results salinity classes are as follows: 1- tidal freshwater, 2 - oligohaline, 3- low mesohaline, 4 - high mesohaline and 5 - polyhaline. The two sediment classes are as follows: 1 - silt clay content $< 40\%$ and 2 - silt clay content $\geq 40\%$. All abundance values are individuals per m^{-2}; biomass values are AFDW g per m^{-2}; and pollution indicative, pollution sensitive and cavnivore/omnivore metrics are percent of abundance or biomass as indicated in tables.

RESULTS

Mainstem

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 1. Water depths varied from 1-17 m reflecting shoal and channel depths. All salinity values were in the polyhaline range with values from 21.3 to 23.0 ppt and bottom dissolved oxygen was generally high with values from 4.5 to 10.4 ppm. Silt-clay content varied from 0.8 to 95.2 % and total volatile solids from 0.4 to 8.0%.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 2. In general the Mainstem of the river had the best benthic community condition as indicated by the highest mean B-IBI value, biomass and Shannon Index (Table 29). In addition the composition of the community was generally the best balanced with pollution indicative species being low and pollution sensitive species having the highest values among the strata studied (Table 29).

The Mainstem of the river had the lowest level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 30, Fig. 3). In addition the percent of bottom with severely degraded benthos (B-IBI less than 2.0) was 4%, less than the average of 12% for all Virginia tidal waters (Table 30, Fig. 4). Table 4 summarizes the B-IBI scores for selected individual metrics. Dominant species are presented in Table 5.

Lafayette River

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 5. Water depths are shallow and varied from 1-3 m. Salinity values were primarily in the polyhaline range with values from 17.0 to 23.2 ppt and bottom dissolved oxygen was generally high with values from 3.4 to 11.8 ppm. Silt-clay content varied from 2.2 to 99.0 % and total volatile solids from 0.0 to 12.6 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 6. The Lafayette River benthic community condition was intermediate among the strata with the Mainstem having the highest values, the Southern Branch with the lowest values and the Lafayette River, Eastern Branch and Western Branch with intermediate values (Tables 6, 29, 30). Stations L18 to L25 tended to have the highest abundance, lowest species diversity, and less abundance of pollution sensitive species (Table 6).

The Lafayette River had intermediate level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 29, Fig. 5). In addition the percent of bottom with severely degraded benthos (B-IBI less than 2.0) was also intermediate with a value of 12 % (Table 30, Fig. 6). The three severely degraded sites were spread throughout the river (Fig. 6). Table 7 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 8.

Western Branch

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 9. Water depths are shallow and varied from 1-4 m. Salinity values were all in the polyhaline range with values from 20.5 to 23.5 ppt and bottom dissolved oxygen was generally high with values from 5.2 to 10.4 ppm. Silt-clay content varied from 0.9 to 99.1 % and total volatile solids from 0.4 to 8.1 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 10. The Western Branch benthic community condition was intermediate among the strata with the Mainstem having the highest values, the Southern Branch with the lowest values and the Lafayette River, Eastern Branch and Western Branch with intermediate values (Tables 10, 29, 30).

The Western Branch had intermediate level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 30, Fig. 7). In addition the percent of bottom with severely degraded benthos (B-IBI less than 2.0) was also intermediate with a value of 20 % (Table 30, Fig.8). The five severely degraded sites were in the middle region of the river (Fig. 8). Table 11 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 12.

Eastern Branch

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 13. Water depths varied greatly from channel depths of 5-9 m to 1-2 m in the shallow upper region. Salinity values were in the polyhaline range in the lower reach of this branch and in the high mesohaline range in the upper reach. Bottom dissolved oxygen was generally lower than the Mainstem, Western Branch and Lafayette River with values from 1.9 to 10.8 ppm. Fourteen sites had bottom oxygen values below 4 ppm. Silt-clay content varied from 4.6 to 98.4 % and total volatile solids from 3.8 to 14.7 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 14. The Eastern Branch benthic community condition was intermediate among the strata with the Mainstem having the highest values, the Southern Branch with the lowest values and the Lafayette River, Eastern Branch and Western Branch with intermediate values (Tables 14, 29, 30).

The Eastern Branch had intermediate level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 30, Fig. 9). In addition the percent of bottom with severely degraded benthos (B-IBI less than 2.0) was also intermediate with a value of 12 % (Table 30, Fig. 10). The three severely degraded sites were in the upper region of the river (Fig. 10). Table 15 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 16.

Southerm Branch

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 17. Water depths varied greatly from channel depths of 7-14 m in the lower reach of the branch to 1-2 m in the upper region. Salinity values were in the polyhaline range in the lower reach of this branch and generally in the high mesohaline range in the upper reach. Bottom dissolved oxygen was generally lowest among the primary branches with all values below 4. Silt-clay content varied from 4.6 to 97.4.4 % and total volatile solids from 1.0 to 15.1 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 18. The Southern Branch benthic community condition was the worst among the strata with the Mainstem having the highest values, the Southern Branch with the lowest values and the Lafayette River, Eastern Branch and Western Branch with intermediate values (Tables 18, 29, 30).

The Southern Branch had the highest level of degraded bottom (B-IBI values less than 3.0) among the primary strata (Table 30, Fig. 11). In addition the percent of bottom with severely degraded benthos (B-IBI less than 2.0) was the highest among all strata with a value of 44 % (Table 30, Fig. 12). The 11 severely degraded sites were found throughout the middle and upper reaches of Southern Branch (Fig. 12). Table 19 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 20.

Scuffletown Creek

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 21. Water depths were shallow ranging from 1-4 m. Salinity values were all in the polyhaline range. Bottom dissolved oxygen was generally high with all values above 4 ppm. Silt-clay content varied from 9.6 to 82.3 % and total volatile solids from 1.0 to 13.5 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 22. The Scuffletown Creek benthic community condition was between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch (Tables 22, 29, 30).

Scuffletown Creek had levels of degraded bottom (B-IBI values less than 3.0) between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch (Table 30, Fig. 13). The percent of bottom with severely degraded

benthos (B-IBI less than 2.0) was between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch with a value of 24 % (Table 30, Fig. 14). The six severely degraded sites were found throughout the creek (Fig. 14). Table 23 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 24.

Jones-Gilligan Creek

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 25. Water depths varied from channel depths of 5-9 m in the lower reach to 1 m in the upper reaches. Salinity values were generally in the polyhaline range with some mesohaline values in the upper reach. Bottom dissolved oxygen was generally high with all but one value above 4 ppm. Silt-clay content varied from 2.1 to 90.1 % and total volatile solids from 0.3 to 16.5 %.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 26. The benthic community condition was similar to Scuffletown Creek being between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch (Tables 27, 29, 30).

Jones-Gilligan Creek had levels of degraded bottom (B-IBI values less than 3.0) the same as Scuffletown Creek and between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch (Table 30, Fig. 13). The percent of bottom with severely degraded benthos (B-IBI less than 2.0) was again the same as Scuffletown Creek and was between the worst condition in the Southern Branch and the values for the Lafayette River, Eastern Branch and Western Branch with a value of 24 % (Table 30, Fig. 14). The six severely degraded sites were found throughout the creek but with five of the six sites near the mouth of the creek system (Fig. 14). Table 27 summarizes the B-IBI scores for selected individual metrics and dominant species are presented in Table 28.

Fixed Point Stations

Environmental Parameters

All physical, chemical and sedimentary parameters are summarized in Table 31.

Benthic Community

Benthic community parameters including the B-IBI value, abundance, biomass, Shannon diversity and selected metrics are summarized by station in Table 32. These stations will be the basis for future long-term trend analyses.

Discussion

The condition of the macrobenthic communities of the Elizabeth River watershed was characterized for five strata consisting of the Mainstem of the River, the Lafayette River, the Southern Branch, Western Branch and Eastern Branch. The five strata can be characterized in terms of benthic community condition into three categories: (1) the best condition in the Mainstem of the river, (2) the worst condition in the Southern Branch, and (3) intermediate condition in the Eastern Branch, Western Branch and Lafayette River (Figs. 15-18). The Mainstem of the river had the highest average B-IBI value of 2.88, the Southern Branch the lowest value of 2.02 and the other branches had values between 2.45 and 2.71 (Table 29, Fig. 18). The resulting estimates of percent bottom failing the Chesapeake Bay Benthic Restoration goals were lowest in the Mainstem (52 ± 20 %), greatest in the Southern Branch (92 ± 11%) and intermediate in the other branches (ranging from 64 to 72%) (Table 30). However, the estimated level of degraded benthic habitats within the Elizabeth River is higher for all five strata compared to the average for all Virginia tidal waters of 41% (1996-1998 average value from Dauer and Rodi 1999). The 1999 average level of degraded benthic habitats was 30 % (Fig. 24 from Dauer, in preparation)

The two strata studied as part of a proposed sediment contaminant remediation study (Scuffletwon Creek and Jones-Gilligan Creek) had average B-IBI values and average levels of degraded bottom intermediate between those for the Southern Branch (Tables 29, 30; Figs. 15-18) and the Lafayette River, Western branch and Eastern Branch.

Compared to the Chesapeake Bay Benthic Restoration Goals the macrobenthic communities of the Elizabeth River can be characterized as (1) having lower than expected species diversity and biomass, (2) abundance levels not different from reference conditions and (3) species composition with levels of pollution indicative species higher than reference conditions and levels of pollution sensitive species lower than reference conditions (Fig. 19-23).

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Figures

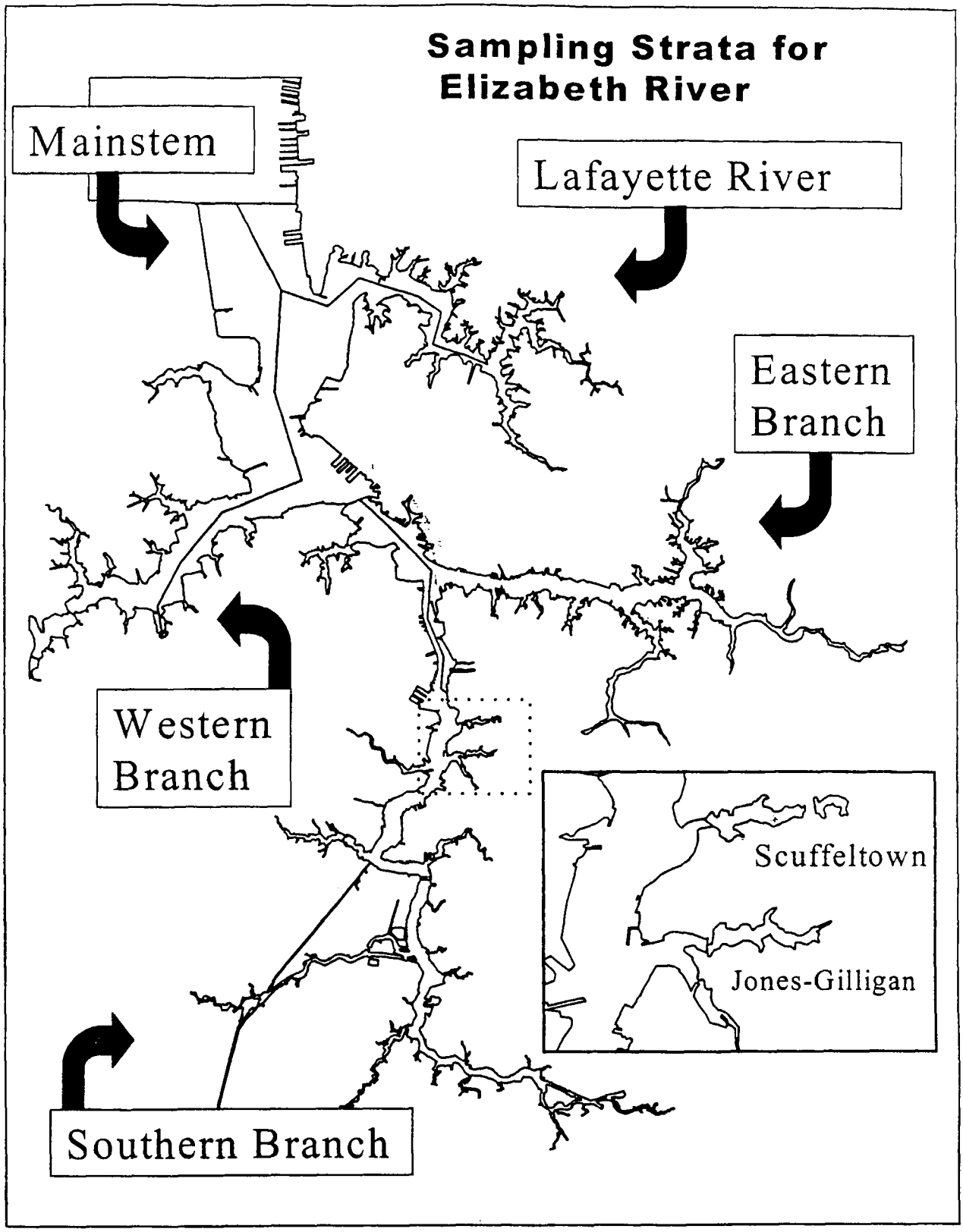

Figure 1. Elizabeth River watershed showing the five major segments sampled. Insert shows Scuffletown Creek and the Jones-Gilligan Creek strata.

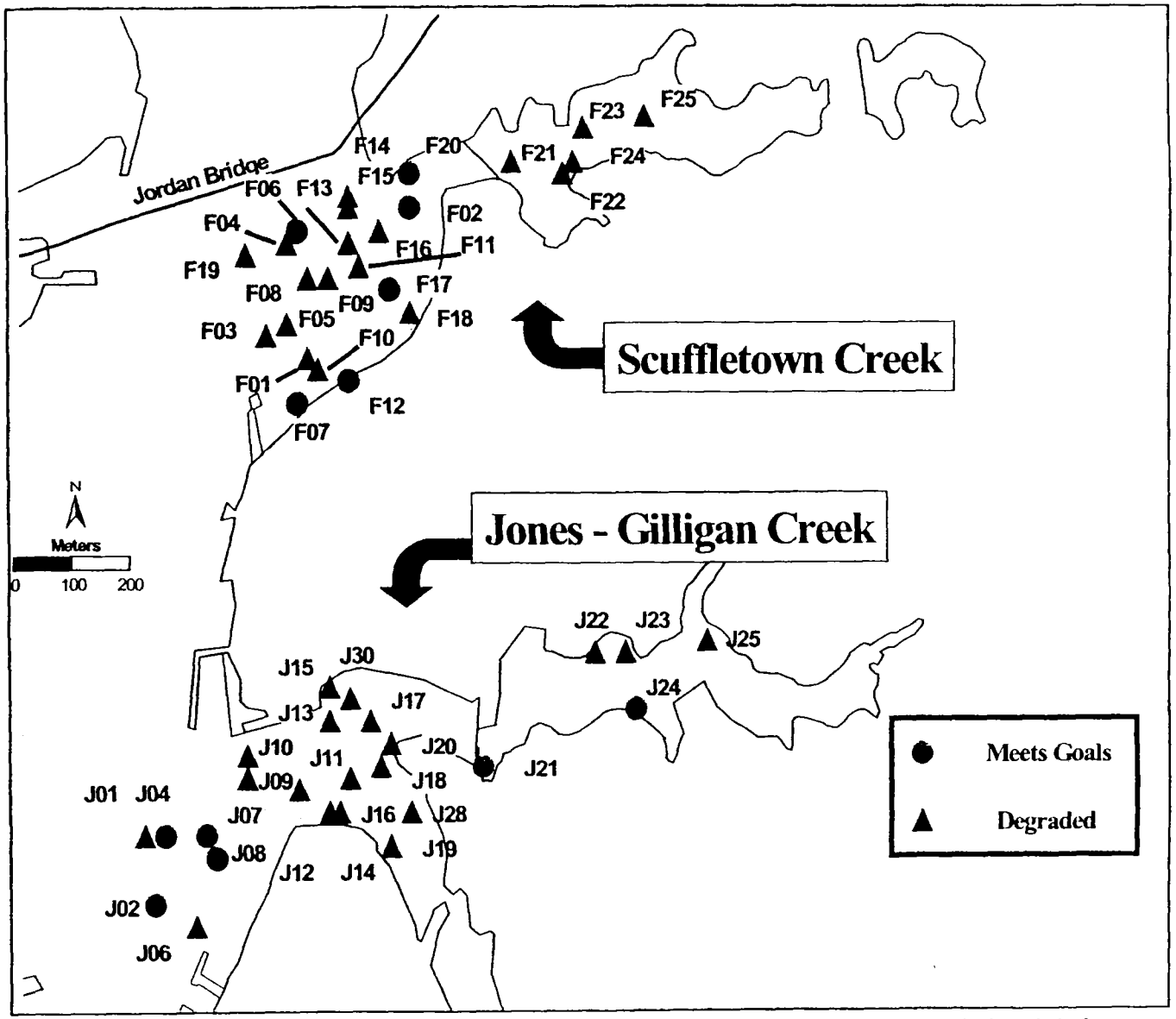

Figure 13. Scuffletown Creek and Jones-Giligan Creek showing the 25 sites sampled and their designations using the B-IBI. In this figure "degraded" includes all sites with a B-IBI value less than 3.00.

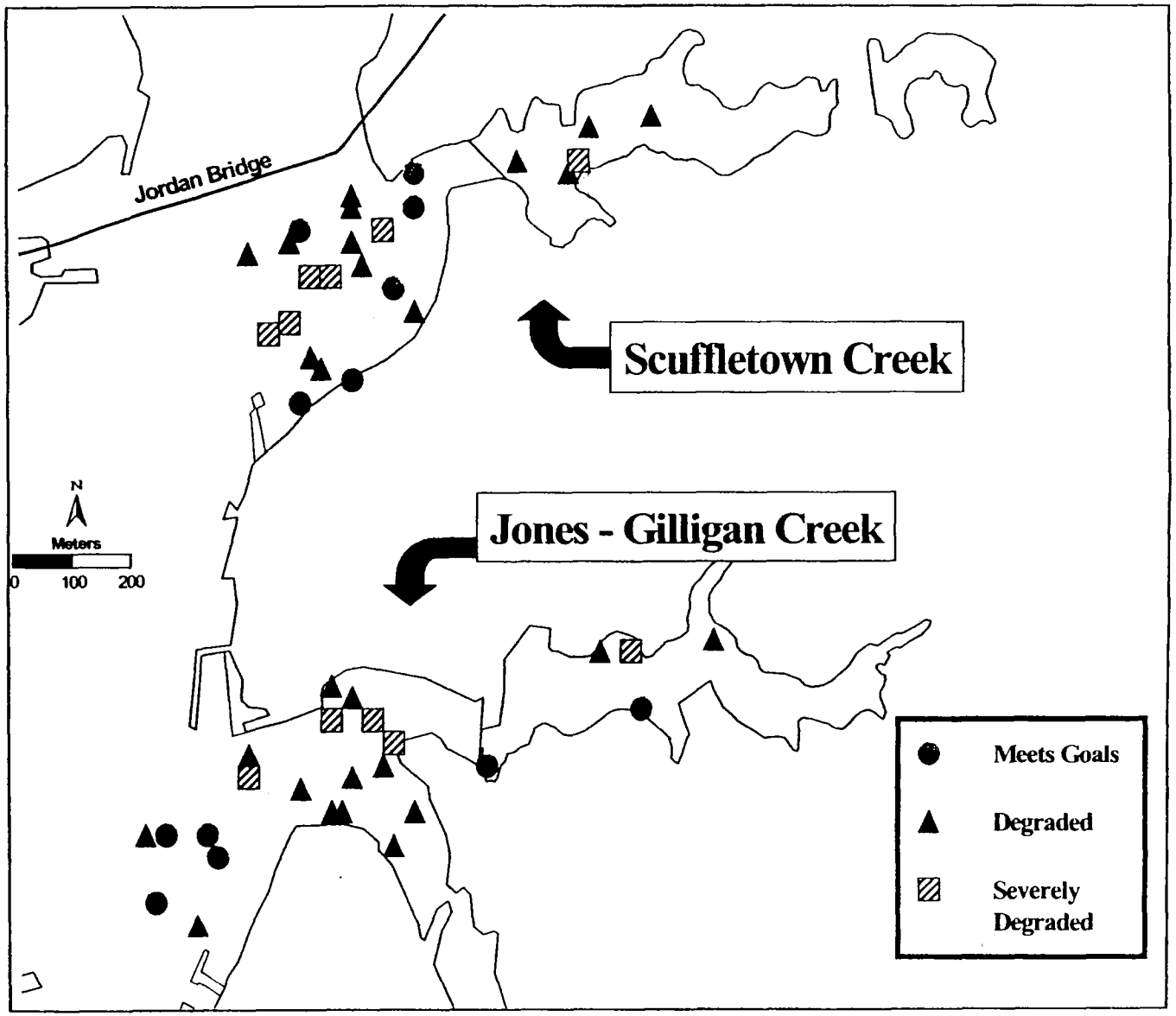

Figure 14. Scuffletown Creek and Jones-Giligan Creek showing the 25 sites sampled and their designations using the B-IBI. In this figure sites with a designation of "severely degraded" are indicated.

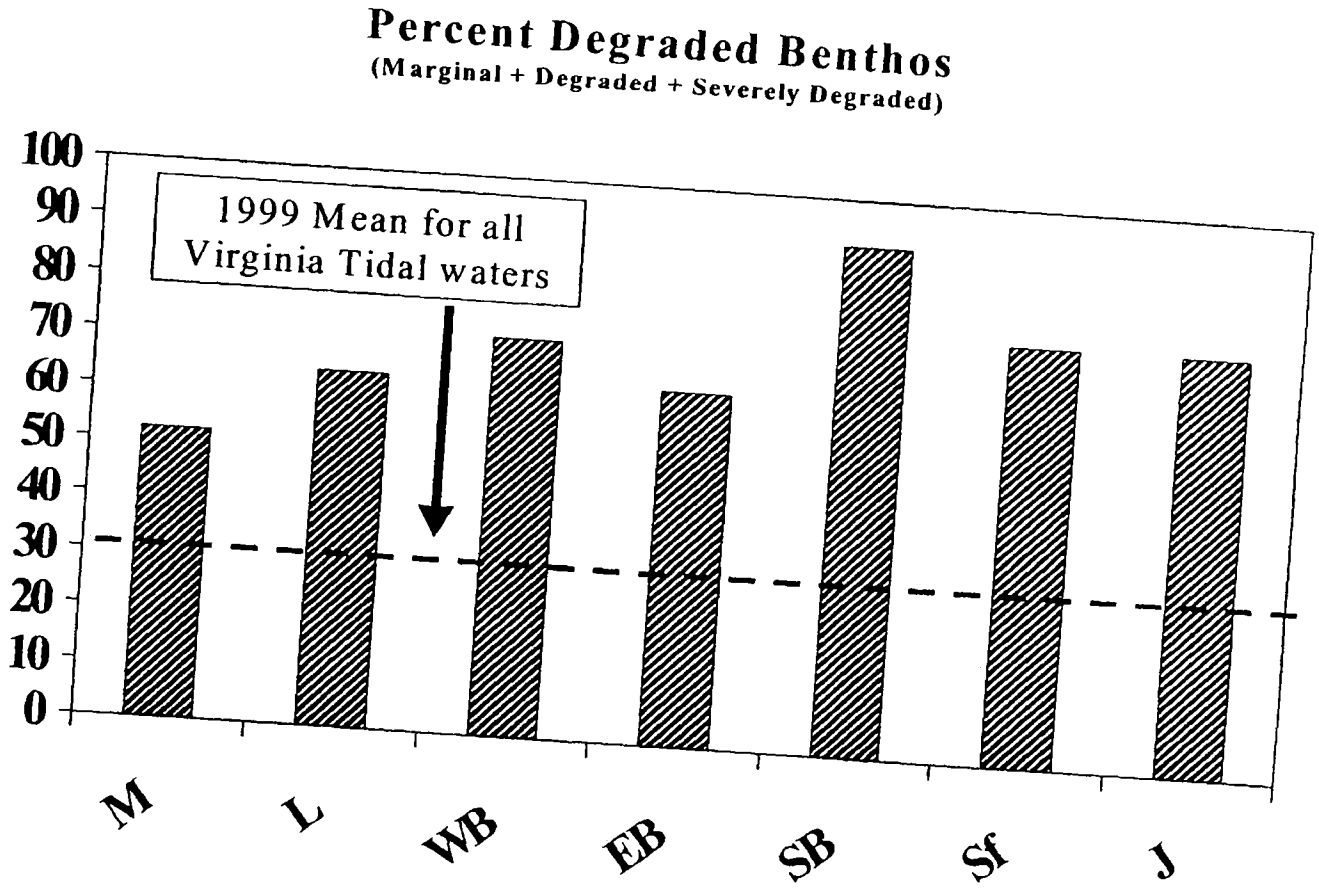

Figure 15. Summary of percent area of each stratum failing the Benthic Restoration Goals. Includes marginal, degraded and severely degraded categories as defined in text. Shown are the seven strata of this study and the 1999 average value for all Virginia tidal waters. Abbreviations: Bay - Mainstem of Chesapeake Bay, M - Mainstem of Elizabeth River, L - Lafayette River, WB - Western Branch, EB - Eastern Branch, SB - Southern Branch, Sf - Suffletown Creek, J - Jones-Gilligan Creek.

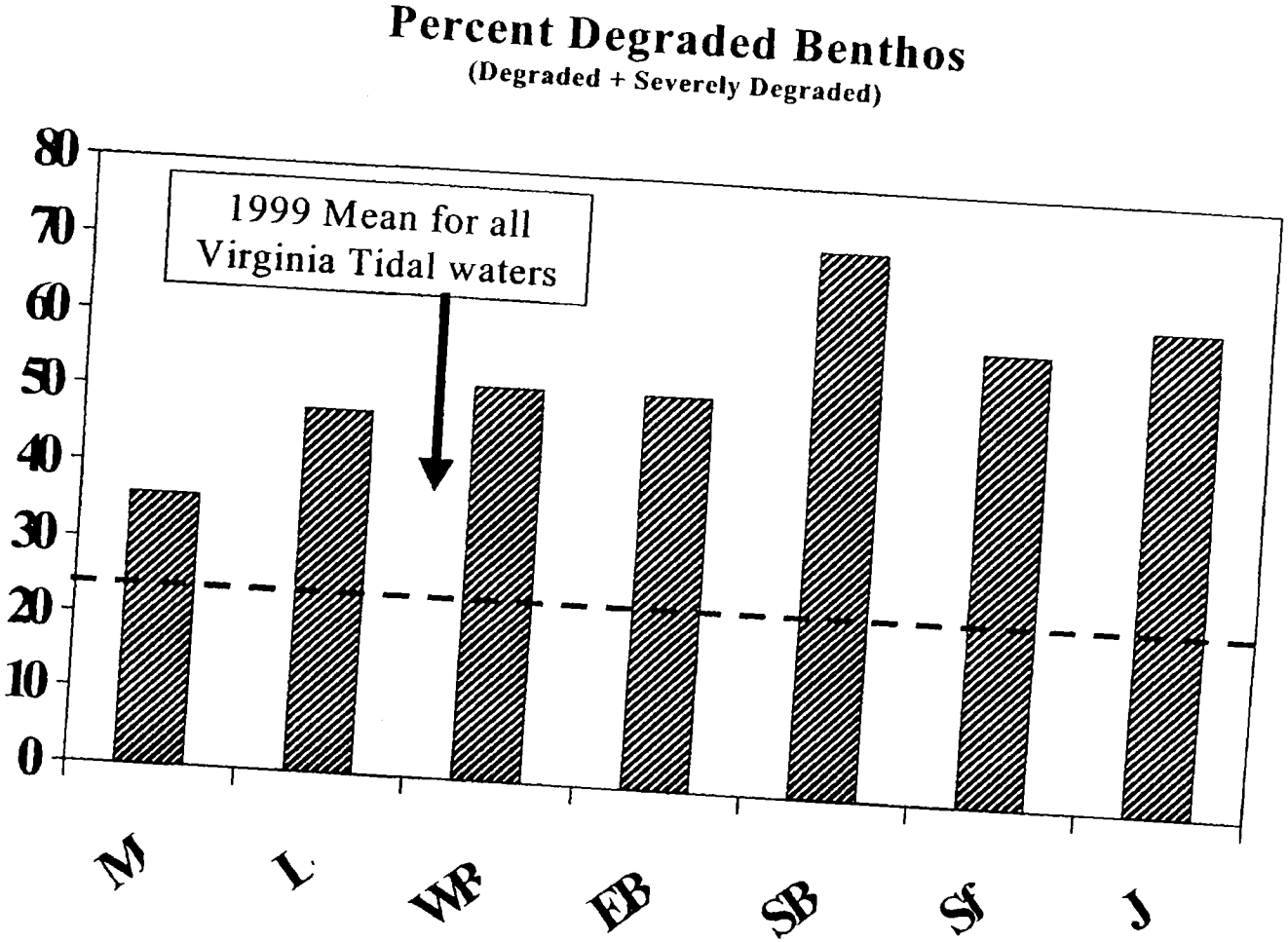

Figure 16. Summary of percent area of each stratum failing the Benthic Restoration Goals. Shown are degraded and severely degraded categories as defined in text. See Figure 15 for abbreviations.

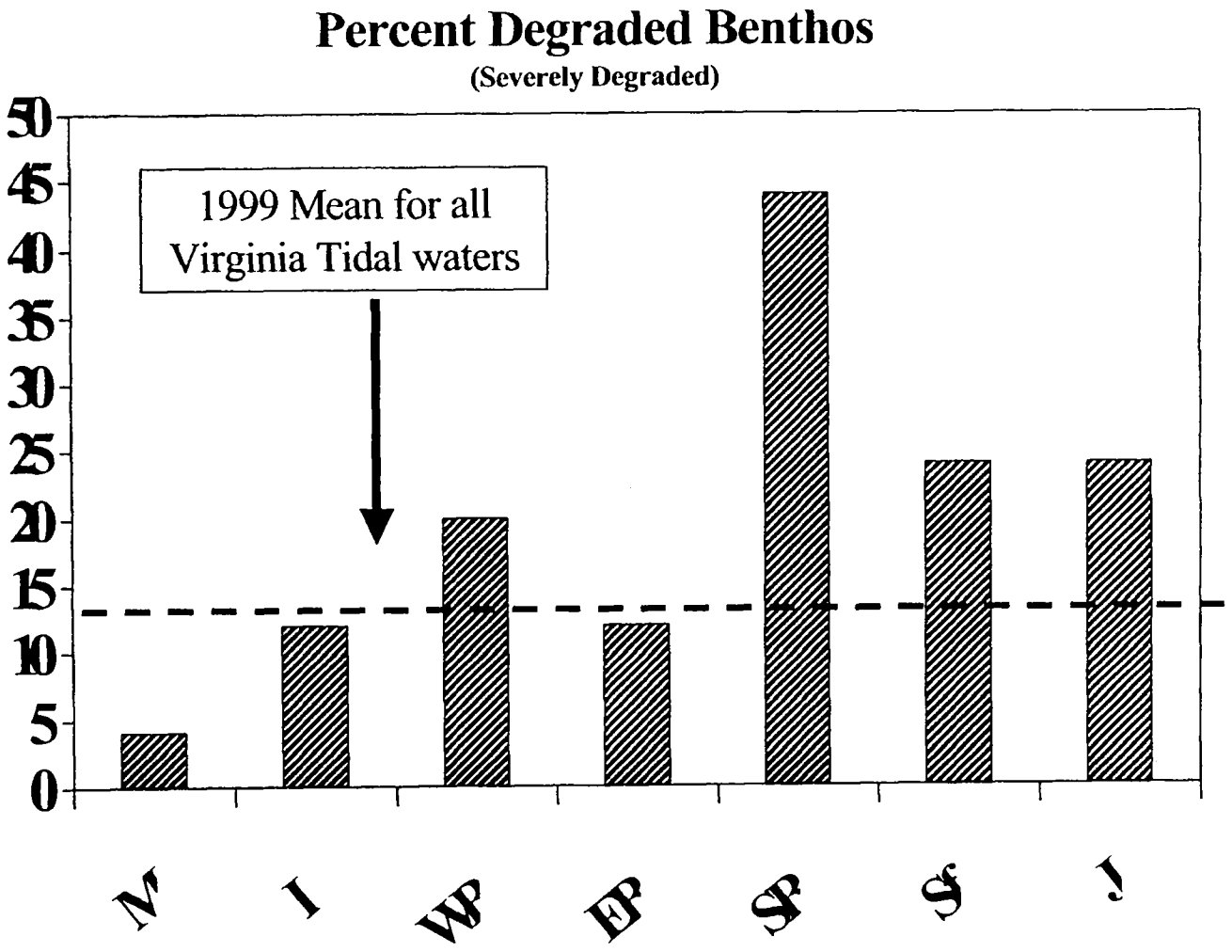

Figure 17. Summary of percent area of each stratum failing the Benthic Restoration Goals. Shown is only the severely degraded category as defined in text. See Figure 15 for abbreviations.

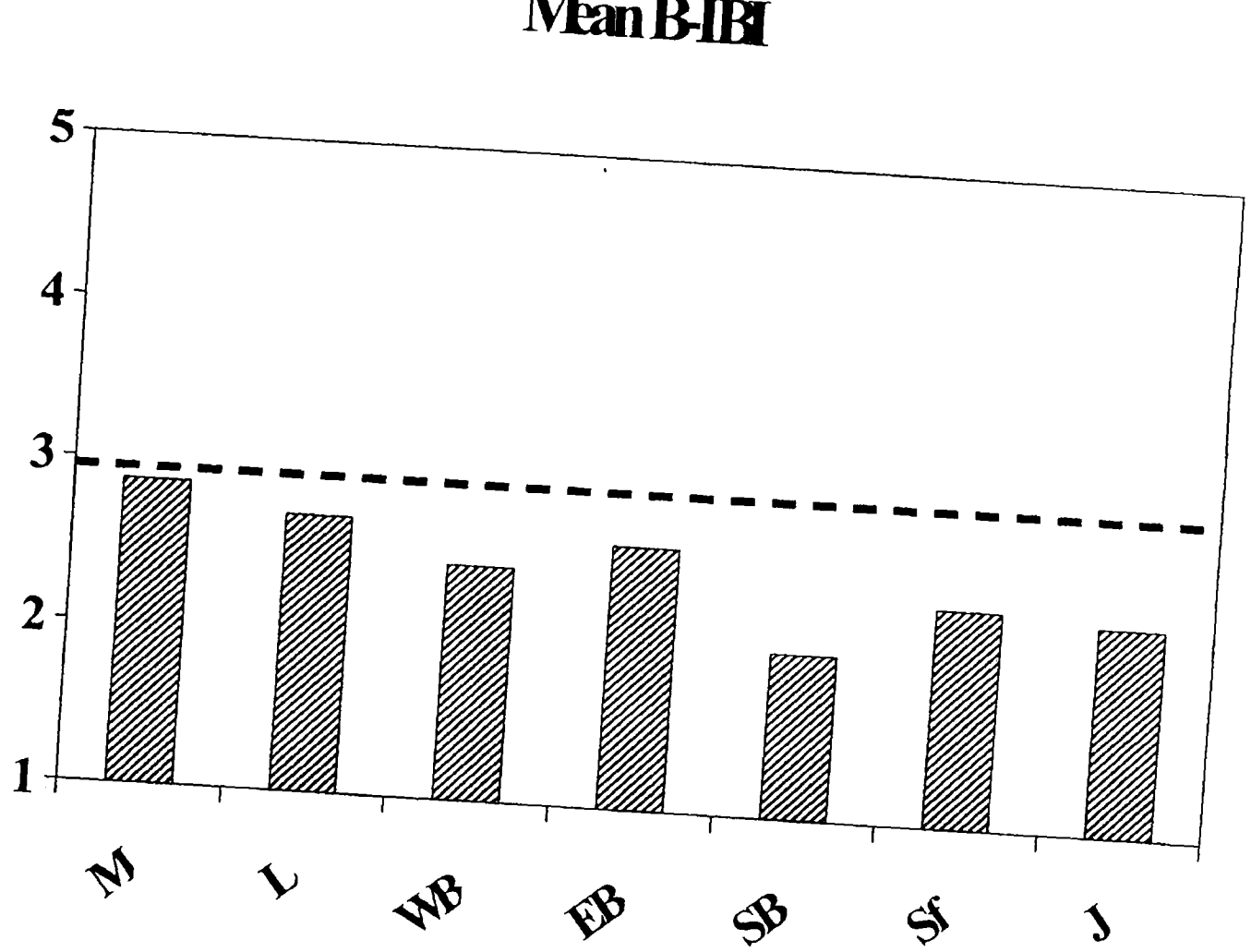

Figure 18. Average B-IBI values for each of the seven strata of this study. See Figure 15 for abbreviations.

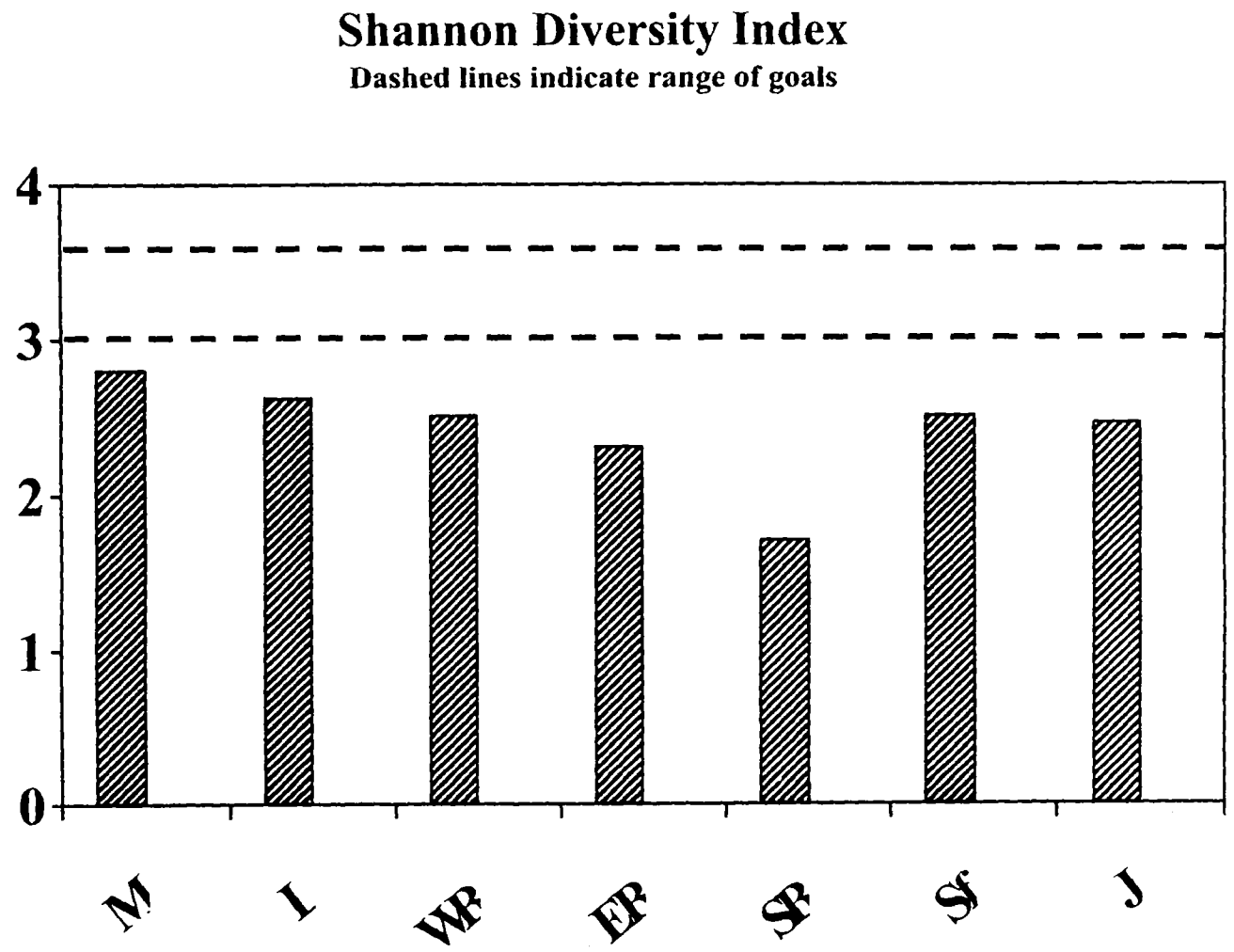

Figure 19. Average Shannon diversity index value for each of the seven strata of this study. Dashed lines indicate range of median values for reference conditions from Weisberg et al. (1997). See Figure 15 for abbreviations.

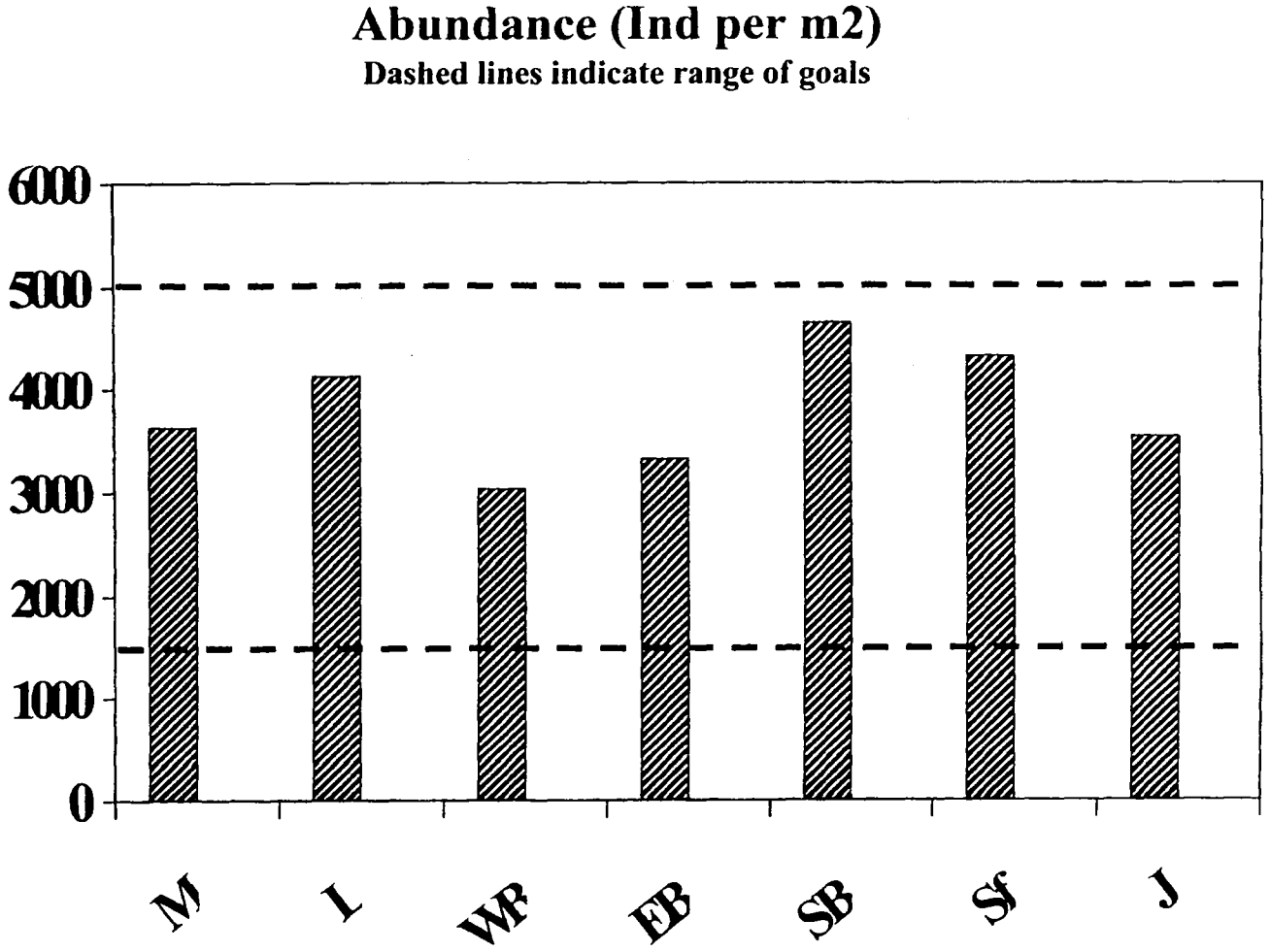

Figure 20. Average abundance of individuals per m^{-2} for each of the seven strata of this study. Dashed lines indicate range of median values for reference conditions from Weisberg et al. (1997). See Figure 15 for abbreviations.

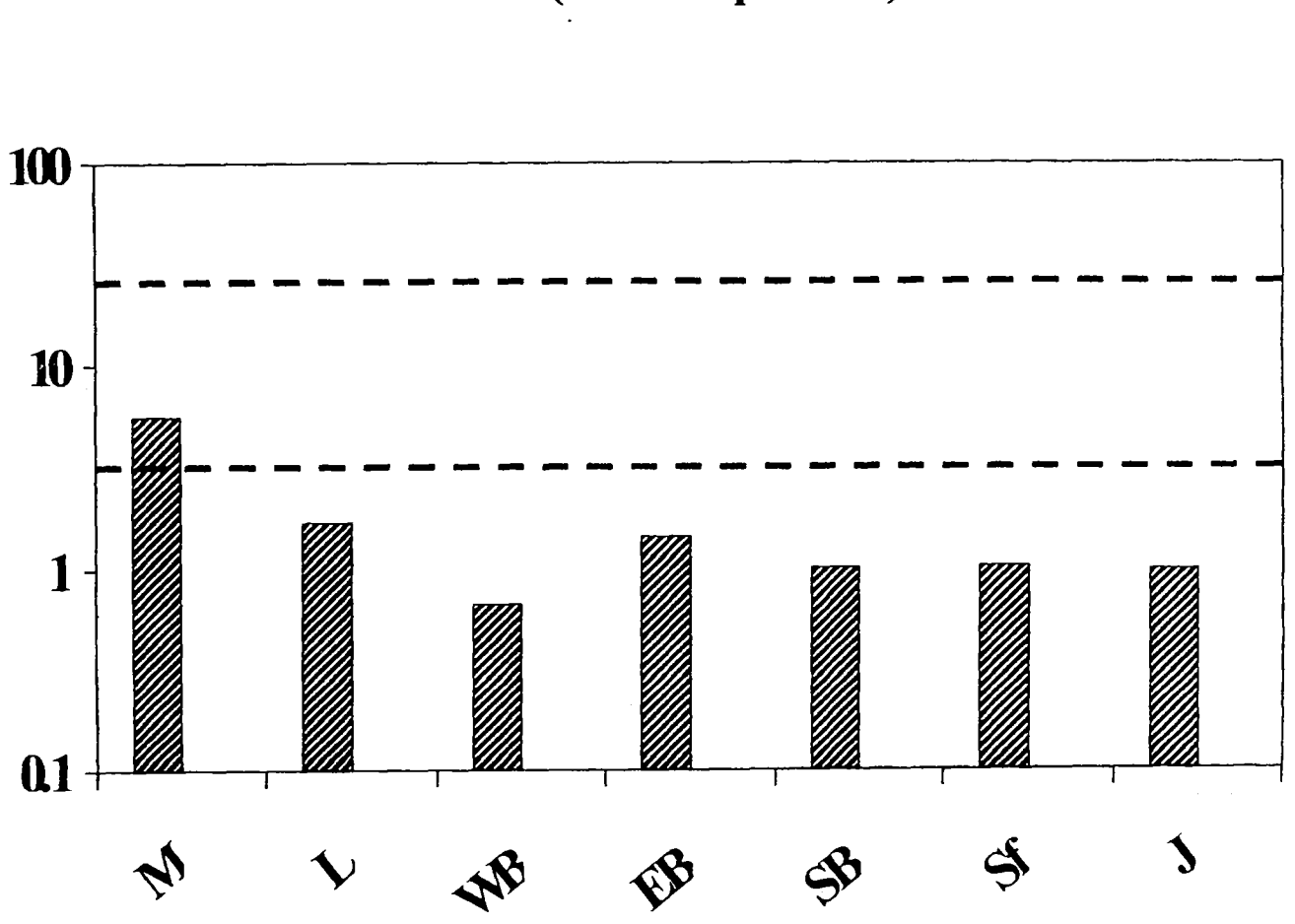

Figure 21. Average AFWD biomass g per m^{-2} for each of the seven strata of this study. Dashed lines indicate range of median values for reference conditions from Weisberg et al. (1997). See Figure 15 for abbreviations.

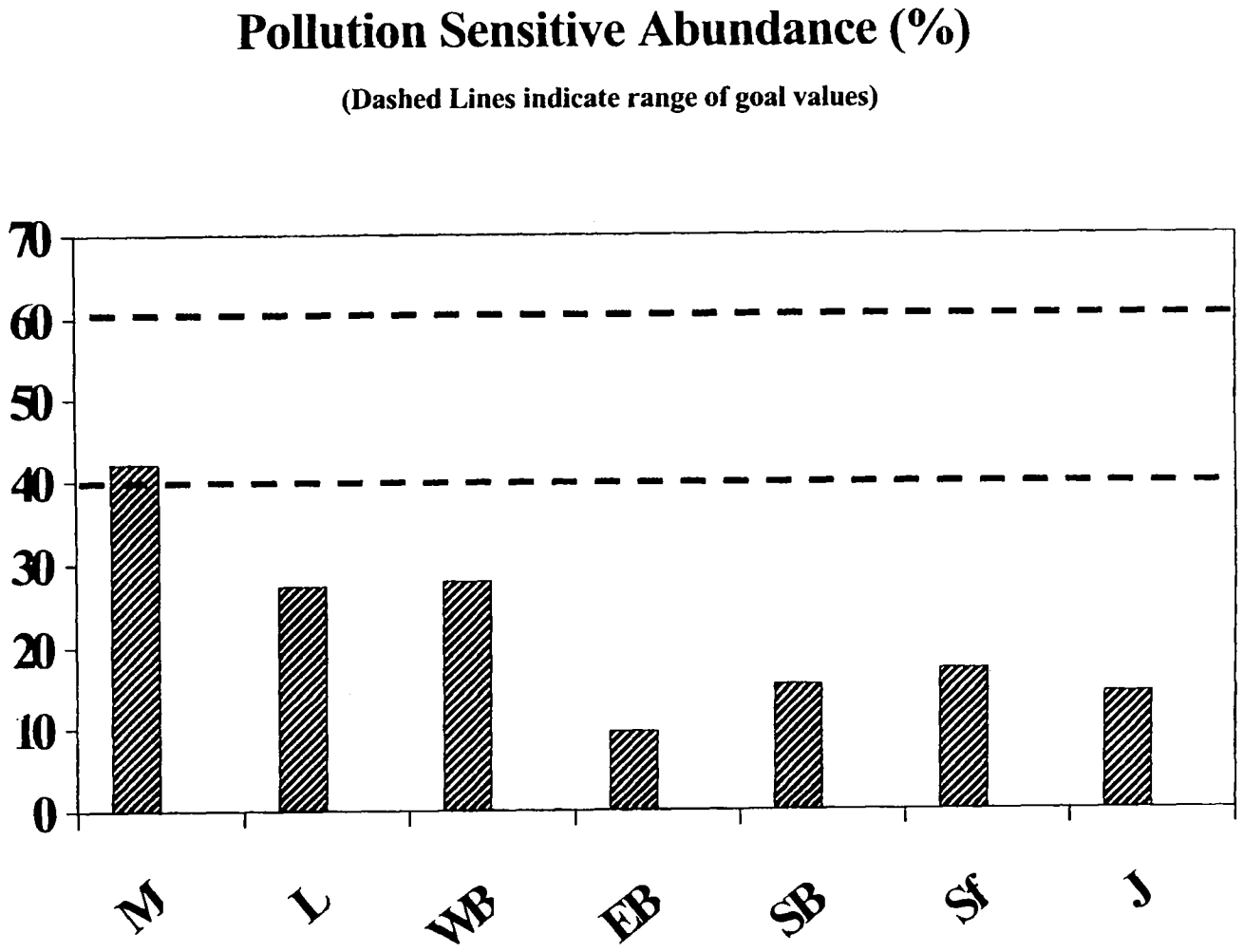

Figure 22. Average percentage of pollution sensitive species abundance for each of the seven strata of this study. Dashed lines indicate range of median values for reference conditions from Weisberg et al. (1997). See Figure 15 for abbreviations.

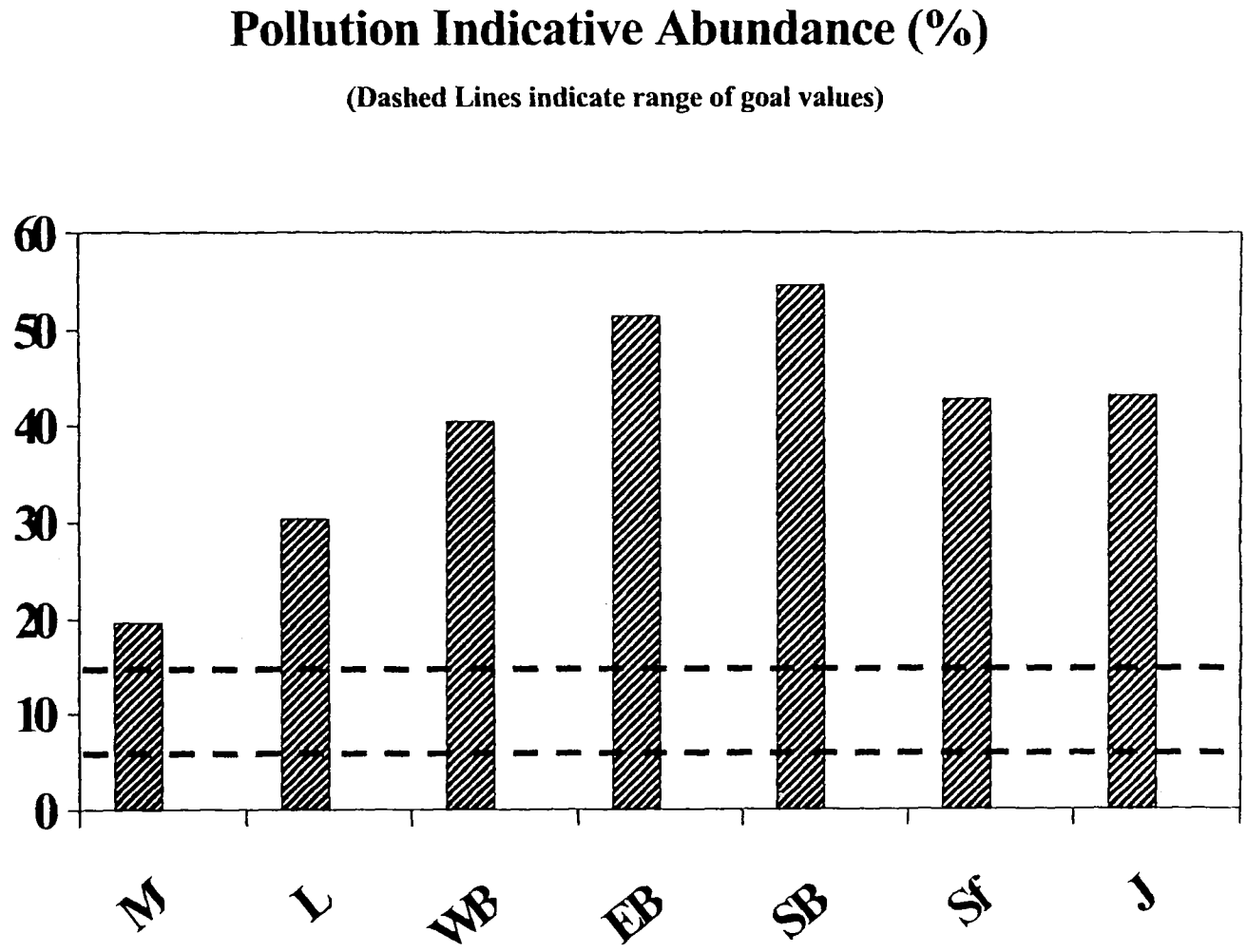

Figure 23. Average percentage of pollution indicative species abundance for each of the seven strata of this study. Dashed lines indicate range of median values for reference conditions from Weisberg et al. (1997). See Figure 15 for abbreviations.

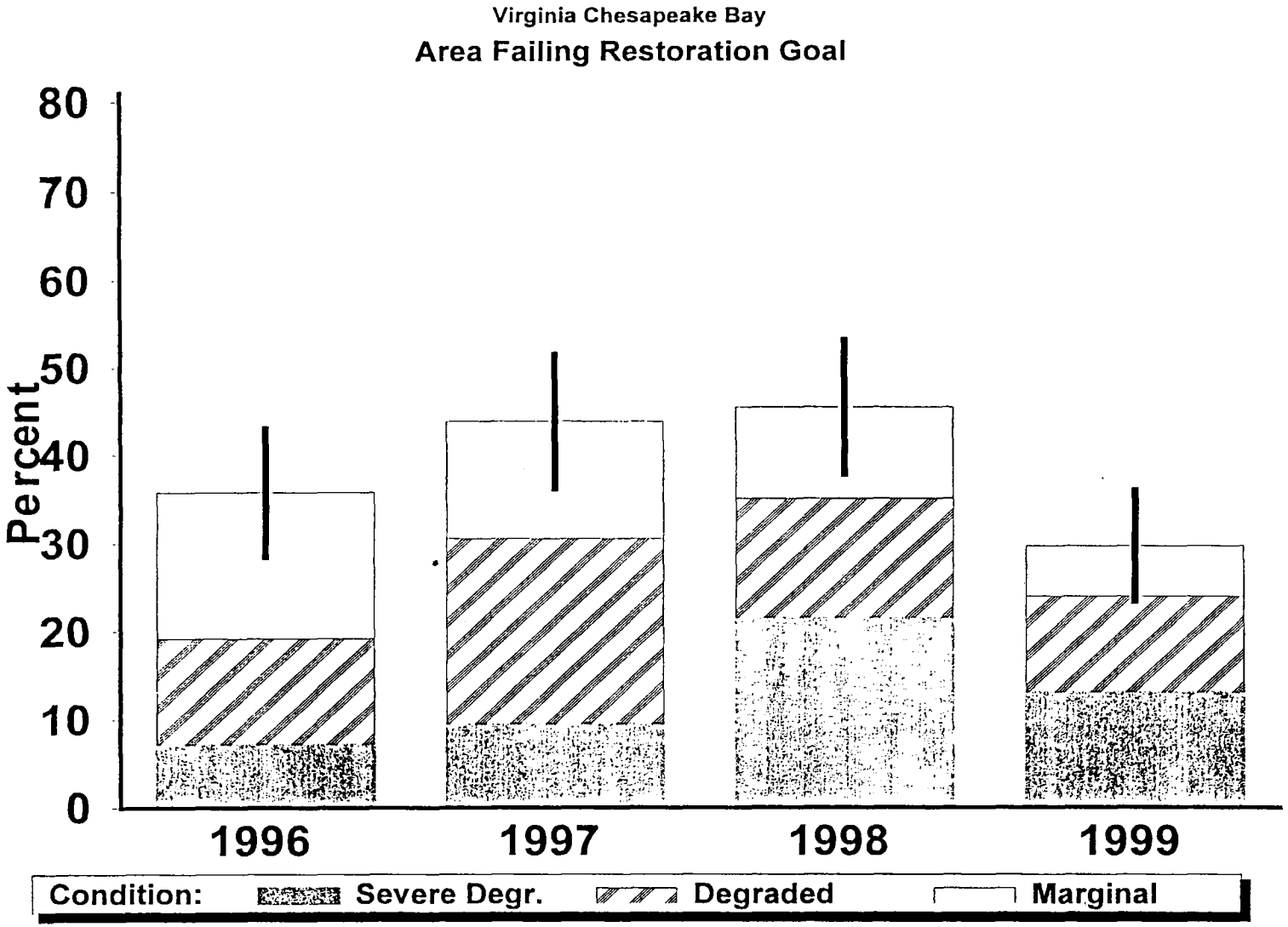

Figure 24. Proportion of the Virginia Bay failing the Chesapeake Bay Benthic Community Restoration Goals from 1996 - 1999. The error bars indicate ± 1 standard error.

Glossary of selected terms

Benthos - refers to organisms that dwell on or within the bottom Includes both hard substratum habitats (e.g. oyster reefs) and sedimentary habitats (sand and mud bottoms).

B-IBI - the benthic index of biotic integrity of Weisberg et al. (1997). The is a multi-metric index that compares the condition of a benthic community to reference conditions.

Fixed Point Stations - stations for long-term trend analysis whose location is unchanged over time.

Habitat - a local environment that has a benthic community distinct for other such habitat types. For the B-IBI of Chesapeake Bay seven habitat types were defined as combinations of salinity and sedimentary types - tidal freshwater, oligohaline, low mesohaline, high mesohaline sand, high mesohaline mud, polyhaline sand and polyhaline mud.

Macrobenthos - a size category of benthic organisms that are retained on a mesh of 0.5 mm.

Metric - a parameter or measurement of benthic community structure (e.g., abundance, biomass, species diversity.

Probability based sampling - all locations within a stratum have an equal chance of being sampled. Allows estimation of the percent of the stratum meeting or failing the benthic restoration goals.

Random Station - a station selected randomly within a stratum. In every succeeding sampling event new random locations are selected.

Reference condition - the structure of benthic communities at reference sites.

Reference sites - sites determined to be minimally impacted by anthropogenic stress. Conditions at theses sites are considered to represent goals for restoration of impacted benthic communities. Reference sites were selected by Weisberg et al. (1997) as those outside highly developed watersheds, distant from any point-source discharge, with no sediment contaminant effect, with no low dissolved oxygen effect and with a low level of organic matter in the sediment.

Restoration Goal - refers to obtaining an average B-IBI value of 3.0 for a benthic community indicating that values for metrics approximate the reference condition.

Stratum - a geographic region of unique ecological condition or managerial interest. In this study the primary strata were the Mainstem of the river, the Lafayette River, the Eastern Branch, Western Branch and Southern Branch. In future years the entire Elizabeth River watershed will be sampled as a single stratum.

Threshold - a value of a metric that determines the B-IBI scoring. For all metrics except abundance and biomass, two thresholds are used - the lower 5th percentile and the 50th percentile (median) of the distribution of values at reference sites. Samples with metric values less than the lower 5th percentile are scored as a 1. Samples with values between the 5th and 50th metrics are scored as 3 and values greater than the 50th percentile are scored as 5. For abundance and biomass, values below the 5th and above the 95th percentile are scored as 1, values between the 5th and 25th and the 75th and 95th percentiles are scored as 3 and values between the 25th and 75th percentiles are scored as 5.

Tables

Table 20. Southern Branch. Dominant Taxa by abundance. Taxon code: A- amphipod, B- bivalve, G - gastropod, H- hemichordate, I - isopod, O - oligochaete, P -polychaete, Ph - phoronid, R - rhynchocoel		
	Name	Abundance per m^{-2}
1	Streblospio benedicti (P)	2082
2	Oligochaeta spp. (O)	831
3	Paraprionospio pinnata (P)	526
4	Tubificoides spp. Group I (O)	229
5	Glycinde solitaria (P)	153
6	Mediomastus ambiseta (P)	123
7	Hemichordata spp. (H)	96
8	Tubificoides heterochaetus (O)	80
9	Heteromastus filiformis (P)	64
10	Cyathura polita (I)	61
11	Nereis succinea (P)	57
12	Laeonereis culveri (P)	51
13	Gyptis brevipalpa (P)	37
14	Loimia medusa (P)	33
15	Leitoscoloplos spp (P).	29

Table 21. Scuffletown Creek. Summary of physical and chemical parameters by sample.

Station	Date collected	Latitude	Longitude	Water Depth (m)	Salinity (ppt)	Dissolved oxygen (ppm)	Silt-Clay Content (%)	Volatile Organics (%)
F01	7/22/99	36.80636	76.28980	1	20.2	5.8	16.1	2.0
F02	7/22/99	36.80644	76.28970	1	20.1	5.2	32.7	4.0
F03	7/21/99	36.80678	76.28920	4	21.6	5.7	67.6	7.0
F04	7/21/99	36.80776	76.28910	2	22	5	65.4	7.3
F05	7/21/99	36.8068	76.28890	2	21.1	6.8	NA	5.2
F06	7/21/99	36.80778	76.28880	3	21.7	5.1	62.8	6.2
F07	7/21/99	36.80586	76.28880	1	20	8.6	11.4	1.0
F08	7/21/99	36.80735	76.28880	3	21.3	6.5	56.3	6.8
F09	7/21/99	36.80736	76.28840	2	21.2	6.4	47.0	5.3
F10	7/21/99	36.80635	76.28830	1	20	9.3	9.6	1.2
F11	7/21/99	36.80746	76.28790	1	20	7.8	12.4	1.9
F12	7/21/99	36.80604	76.28770	1	19.9	9.1	15.7	2.0
F13	7/21/99	36.80794	76.28770	2	20.3	6.2	72.2	8.2
F14	7/21/99	36.8084	76.28760	1	20	8.2	46.4	7.2
F15	7/21/99	36.80826	76.28760	1	20.1	7	39.6	5.7
F16	7/21/99	36.80803	76.28720	1	20	7	70.5	6.5
F17	7/21/99	36.80721	76.28700	1	19.9	8.9	17.2	1.8
F18	7/21/99	36.80708	76.28670	1	20.1	7.8	18.5	1.7
F19	7/21/99	36.80866	76.28650	4	21.7	5.2	38.3	4.2
F20	7/21/99	36.8086	76.28470	1	19.1	7.1	24.8	4.6
F21	7/21/99	36.80801	76.28410	1	20.3	4.4	69.2	9.7
F22	7/21/99	36.80856	76.28340	1	19.6	5.5	78.2	11.0
F23	7/21/99	36.80911	76.28330	1	19.4	6.9	63.9	13.5
F24	7/21/99	36.80873	76.28330	1	19.7	6.4	72.0	11.3
F25	7/21/99	36.80935	76.28120	1	19.4	4.9	82.3	9.8

Table 22. Scuffletown Creek. Summary of benthic community parameters by sample.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
F01	2.333	1996	0.816	2.499	46.6	9.1	8.3	13.9	9.1
F02	3.000	6146	1.950	2.425	32.1	3.7	4.7	9.3	13.7
F03	1.333	4604	0.476	1.759	60.1	0.0	38.1	0.0	1.5
F04	2.333	2019	0.635	2.739	42.7	30.3	28.6	21.4	13.5
F05	1.667	1383	0.249	2.057	9.8	50.8	18.2	18.2	3.3
F06	3.000	1157	1.338	2.864	7.8	31.4	5.1	42.4	25.5
F07	3.000	6396	1.520	2.822	37.2	6.7	6.0	13.4	11.7
F08	1.667	953	0.794	3.168	16.7	33.3	28.6	11.4	23.8
F09	1.333	4332	0.476	2.374	32.5	38.7	23.8	14.3	3.7
F10	2.333	2517	0.748	2.928	41.4	9.9	15.2	24.2	16.2
F11	2.000	6486	0.885	2.024	64.7	16.4	25.6	15.4	3.8
F12	3.667	3742	1.247	2.805	35.2	4.8	3.6	7.3	12.1
F13	2.000	5421	0.998	2.528	44.4	25.1	38.6	15.9	1.3
F14	2.667	4740	0.862	2.496	46.9	32.1	13.2	42.1	9.1
F15	2.667	1814	1.338	3.258	38.8	13.8	20.3	10.2	12.5
F16	1.667	3969	0.975	2.203	48.0	34.9	32.6	14.0	5.1
F17	3.000	5602	1.656	2.957	37.7	7.7	11.0	16.4	7.3
F18	2.667	5829	1.383	2.707	52.9	9.7	6.6	21.3	15.2
F19	2.667	3856	0.544	2.479	45.9	30.0	29.2	25.0	3.5
F20	3.333	4150	1.406	3.093	43.2	11.5	8.1	16.1	19.1
F21	2.333	4196	0.748	2.046	68.1	6.5	12.1	42.4	8.1
F22	2.333	11068	0.953	2.585	33.2	4.1	9.5	31.0	9.4
F23	2.000	1043	0.522	2.292	52.2	13.0	8.7	17.4	13.0
F24	1.667	9639	2.041	2.365	51.3	6.1	7.8	16.7	9.2
F25	2.000	5284	1.383	1.119	79.8	0.4	14.8	1.6	5.6
Mean	2.347	4334	1.038	2.504	42.8	17.2	16.7	18.5	10.3
St Error	0.124	507	0.094	0.095	3.3	2.8	2.2	2.2	1.3

Table 23. Scuffletown Creek. Summary of benthic community parameters scores of the B-IBI.

Station	BIBI	Salinity Class	Sediment Class	Shannon Index	Abundance	Biomass	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance	Deep Deposit Feeders
F01	2.333	5	1	1	3	1	3		1			5
F02	3.000	5	1	1	3	3	5		1			5
F03	1.333	5	2	1	3	1	1			1	1	
F04	2.333	5	2	3	5	3	1			1	1	
F05	1.667	5	2	1	3	1	3			1	1	
F06	3.000	5	2	3	3	3	3			3	3	
F07	3.000	5	1	3	3	3	3		1			5
F08	1.667	5	2	3	1	3	1			1	1	
F09	1.333	5	2	1	3	1	1			1	1	
F10	2.333	5	1	3	3	1	1		1			5
F11	2.000	5	1	1	3	1	1		1			5
F12	3.667	5	1	3	5	3	5		1			5
F13	2.000	5	2	3	3	3	1			1	1	
F14	2.667	5	2	3	3	3	3			3	1	
F15	2.667	5	1	3	3	3	1		1			5
F16	1.667	5	2	1	3	3	1			1	1	
F17	3.000	5	1	3	3	3	3		1			5
F18	2.667	5	1	3	3	3	3		1			3
F19	2.667	5	1	1	5	1	1		3			5
F20	3.333	5	1	3	5	3	3		1			5
F21	2.333	5	2	1	3	3	3			3	1	
F22	2.333	5	2	3	1	3	3			3	1	
F23	2.000	5	2	1	3	3	3			1	1	
F24	1.667	5	2	1	1	3	3			1	1	
F25	2.000	5	2	1	3	3	3			1	1	

Table 24. Scuffletown Creek. Dominant Taxa by abundance. Taxon code: A- amphipod, B- bivalve, C - cumacean, G - gastropod, H- hemichordate, I - isopod, O - oligochaete, P -polychaete, Ph - phoronid, R - rhynchocoel

	Name	Abundance per m^{-2}
1	Streblospio benedicti (P)	1888
2	Mediomastus ambiseta (P)	370
3	Tubificoides spp. Group I (O)	356
4	Leitoscoloplos spp. (P)	298
5	Heteromastus filiformis (P)	281
6	Tubificoides heterochaetus (O)	228
7	Capitella capitata (P)	165
8	Cyathura polita (I)	109
9	Leucon americanus (C)	95
10	Nemertea spp. (R)	77
11	Cyclaspis varians (C)	73
12	Glycinde solitaria (P)	66
13	Eteone heteropoda (P)	64
14	Caulleriella killariensis (P)	40
15	Nereis succinea (P)	37

Table 25. Jones-Giligan Creek. Summary of physical and chemical parameters by sample.

Station	Date collected	Latitude	Longitude	Water Depth (m)	Salinity (ppt)	Dissolved oxygen (ppm)	Silt-Clay Content (%)	Volatile Organics (%)
G01	7/22/99	36.80036	76.29150	9	23.8	4.3	79.8	8.5
G02	7/22/99	36.79953	76.29140	1	19.7	11.1	41.0	12.5
G04	7/22/99	36.80038	76.29120	2	20.2	8.7	16.1	2.0
G06	7/22/99	36.79919	76.29070	6	22.4	4.2	6.9	0.5
G07	7/22/99	36.80044	76.29040	5	21.6	4.9	87.0	7.0
G08	7/22/99	36.80014	76.29020	3	21.1	5.3	37.7	3.1
G09	7/22/99	36.80106	76.28980	9	23.8	4	85.1	6.1
G10	7/22/99	36.80123	76.28980	5	21.4	3.8	55.0	4.13
G11	7/22/99	36.80101	76.28860	5	23	4.2	81.4	6.5
G12	7/22/99	36.80044	76.28830	1	19.6	7.2	2.1	0.3
G13	7/22/99	36.80175	76.28820	5	21	4.6	15.5	2.0
G14	7/22/99	36.80043	76.28810	1	19.6	11.2	18.4	5.8
G15	7/22/99	36.80219	76.28810	3	20	4.3	20.1	2.7
G16	7/22/99	36.80106	76.28760	3	19.8	6.2	90.1	7.2
G17	7/22/99	36.80184	76.28740	3	21.1	4.2	28.9	3.0
G18	7/22/99	36.80121	76.28720	1	18.6	6.8	81.9	6.3
G19	7/22/99	36.80021	76.28690	1	19.3	10.1	8.8	1.7
G20	7/22/99	36.8015	76.28680	1	17	6.4	28.2	4.4
G21	7/22/99	36.80118	76.28520	1	18.5	6.1	52.9	16.5
G22	7/22/99	36.80268	76.28300	1	12.3	8.3	78.5	9.7
G23	7/22/99	36.80264	76.28240	1	11	7.2	77.4	8.9
G24	7/22/99	36.80205	76.28210	1	18.8	7	74.3	9.5
G25	7/22/99	36.80277	76.28070	1	18.3	8.4	75.4	9.0
G28	7/22/99	36.80071	76.28680	1	19.7	12.6	40.5	4.5
G30	7/22/99	36.80206	76.28780	2	20.4	4.3	37.4	3.9

Table 26. Jones and Gilligan Creeks. Summary of benthic community parameters by sample.

Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
G01	2.000	1293	0.295	2.276	50.9	12.3	15.4	30.8	10.5
G02	3.333	3130	1.928	3.134	42.8	15.2	2.4	63.5	18.1
G04	3.000	3538	0.998	2.925	48.1	17.3	6.8	6.8	10.9
G06	2.667	2926	0.885	3.228	27.9	31.8	25.6	15.4	7.8
G07	3.000	1315	0.726	2.679	48.3	15.5	12.5	62.5	12.1
G08	3.000	703	0.658	3.289	3.2	29.0	3.4	10.3	45.2
G09	1.000	726	0.204	2.309	25.0	18.8	22.2	22.2	12.5
G10	2.667	1361	0.454	3.196	25.0	41.7	15.0	30.0	25.0
G11	2.333	522	0.295	2.941	17.4	39.1	23.1	30.8	43.5
G12	2.333	2903	0.386	2.719	50.0	1.6	11.8	11.8	27.3
G13	1.333	8301	1.111	1.914	61.2	6.6	24.5	26.5	2.7
G14	2.333	3062	1.293	2.389	65.2	11.9	21.1	45.6	17.8
G15	2.333	2472	0.612	2.557	48.6	3.7	7.4	3.7	6.4
G16	2.000	386	0.318	2.534	17.6	23.5	7.1	57.1	23.5
G17	1.667	1157	0.431	2.643	49.0	3.9	21.1	21.1	11.8
G18	2.333	204	0.136	2.419	0.0	22.2	0.0	16.7	33.3
G19	2.333	7326	1.45152	2.137	54.8	7.1	17.2	42.2	9.0
G20	1.333	9049	1.5876	1.413	84.0	4.3	11.4	60.0	6.8
G21	3.000	726	0.52164	3.524	21.9	25.0	8.7	39.1	28.1
G22	2.000	5307	1.134	2.139	58.5	2.1	14.0	8.0	9.4
G23	1.800	6486	1.40616	2.369	51.0	4.2	12.9	8.1	9.4
G24	3.000	5557	3.24324	2.891	42.4	4.9	4.9	25.9	9.0
G25	2.000	6600	2.268	2.351	45.7	2.4	8.0	2.0	14.8
G28	2.667	4627	0.81648	2.464	60.3	10.8	11.1	41.7	17.6
G30	1.667	8618	1.474	1.187	82.4	1.6	46.2	27.7	0.8
Mean	2.285	3532	0.985	2.545	43.2	14.3	14.1	28.4	16.5
St Error	0.122	572	0.147	0.111	4.3	2.4	2.0	3.8	2.3

Table 27. Jones-Gilligan Creek Creek. Summary of benthic community parameters scores of the B-IBI.

Station	BIBI	Salinity Class	Sediment Class	Shannon Index	Abundance	Biomass	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance	Deep Deposit Feeders
G01	2.000	5	2	1	3	1	3			3	1	
G02	3.333	5	2	3	3	3	5			5	1	
G04	3.000	5	1	3	5	1	3		1			5
G06	2.667	5	1	3	3	1	1		3			5
G07	3.000	5	2	3	3	3	3			5	1	
G08	3.000	5	1	3	1	1	5		3			5
G09	1.000	5	2	1	1	1	1			1	1	
G10	2.667	5	2	3	3	1	3			3	3	
G11	2.333	5	2	3	1	1	1			3	5	
G12	2.333	5	1	3	3	1	3		1			3
G13	1.333	5	1	1	1	3	1		1			1
G14	2.333	5	1	1	5	3	1		1			3
G15	2.333	5	1	1	3	1	3		1			5
G16	2.000	5	2	3	1	1	3			3	1	
G17	1.667	5	1	1	1	1	1		1			5
G18	2.333	5	2	3	1	1	5			1	3	
G19	2.333	5	1	1	3	3	1		1			5
G20	1.333	4	1	1	1	3		1	1		1	
G21	3.000	5	2	5	1	3	3			3	3	
G22	2.000	4	2	3	1	3	3			1	1	
G23	1.800	3		3	1	3		1		1		
G24	3.000	5	2	3	3	5	5			1	1	
G25	2.000	5	2	1	3	3	3			1	1	
G28	2.667	5	2	3	3	3	3			3	1	

Table 28. Jones-Gilligan Creek. Dominant Taxa by abundance. Taxon code: A- amphipod, B- bivalve, C - cumacean, G - gastropod, H- hemichordate, I - isopod, O - oligochaete, P -polychaete, Ph - phoronid, R - rhynchocoel		
	Name	Abundance per m^{-2}
1	Streblospio benedicti (P)	1921
2	Tubificoides spp. Group I (O)	240
3	Tubificoides heterochaetus (O)	158
4	Caulleriella killariensis (P)	134
5	Leitoscoloplos spp. (P)	134
6	Mediomastus ambiseta (P)	97
7	Heteromastus filiformis (P)	95
8	Cyathura polita (I)	92
9	Capitella capitata (P)	70
10	Laeonereis culveri (P)	65
11	Hobsonia florida (P)	64
12	Glycinde solitaria (P)	53
13	Edotea triloba (I)	50
14	Cyclaspis varians (C)	44
15	Leucon americanusn (C)	44

Table 29. Summary of benthic community parameters by stratum.									
Station	BIBI	Abundance	Biomass	Shannon Index	Pollution Indicative Abundance	Pollution Sensitive Abundance	Pollution Indicative Biomass	Pollution Sensitive Biomass	Carnivore Omnivore Abundance
Mainstem									
Mean	2.880	3636	5.599	2.800	19.5	42.1	14.5	42.7	17.0
St Error	0.153	484	3.131	0.103	3.2	4.0	2.7	5.6	2.1
Lafayette River									
Mean	2.707	4129	1.709	2.611	30.3	27.3	15.5	30.2	9.3
St Error	0.161	421	0.819	0.106	3.1	4.4	3.1	4.5	1.3
Eastern Branch									
Mean	2.627	3332	1.447	2.3	51.4	9.7	11.0	18.9	11.6
St Error	0.152	285	0.299	0.2	4.6	2.3	1.8	3.5	1.3
Western Branch									
Mean	2.453	3038	0.664	2.5	40.4	27.9	16.0	28.3	10.6
St Error	0.126	199	0.055	0.1	2.3	2.8	2.7	3.0	1.1
Southern Branch									
Mean	2.021	4656	1.020	1.7	54.6	15.4	30.6	24.1	16.2
St Error	0.140	988	0.247	0.2	6.4	2.9	6.1	3.7	3.9
Scuffletown Creek									
Mean	2.347	4334	1.038	2.504	42.8	17.2	16.7	18.5	10.3
St Error	0.124	507	0.094	0.095	3.3	2.8	2.2	2.2	1.3
Jones - Gilligan Creeks									
Mean	2.285	3532	0.985	2.545	43.2	14.3	14.1	28.4	16.5
St Error	0.122	572	0.147	0.111	4.3	2.4	2.0	3.8	2.3

Table 30. Summary of area of each stratum (± 95% confidence interval) failing the Benthic Restoration Goals. Virginia Tidal Waters data is the average value for 1996-1998 for all regions from tidal freshwater through polyhaline from Dauer and Rodi (1999). The 1999 values is show separately for comparison with data of this study collected in 1999.

Strata within the Elizabeth River	Percent Degraded	% Marginal	% Degraded	% Severely Degraded	% Degraded plus Severely Degraded
Mainstem of River	52 ± 20	16	32	4	36
Lafayette River	64 ± 19	16	36	12	48
Eastern Branch	64 ± 19	12	40	12	52
Western Branch	72 ± 18	20	32	20	52
Southern Branch	92 ± 11	20	28	44	72
Scuffletown Creek	76 ± 17	16	36	24	60
Jones/Gilligan Creek	76 ± 17	12	40	24	64
Virginia Chesapeake Bay					
Virginia Tidal Waters (1996-1998)	41 ± 11	14	14	12	26
Virginia Tidal Waters (1999)	38 ± 11	16	12	9	21

Table 31. Fixed Pont Stations of the Elizabeth River. Summary of physical and chemical parameters by sample.								
Station	Date collected	Latitude	Longitude	Water Depth (m)	Salinity (ppt)	Dissolved oxygen (ppm)	Silt-Clay Content (%)	Volatile Organics (%)
Mainstem								
ELC1	8/20/99	36.87960	76.34755	2.000	21	4.1	25.8	1.7
ELD1	8/13/99	36.86142	76.33573	1.000	21.9	7.6	3.2	4.1
ELF1	8/13/99	36.84861	76.29667	5.000	21.8	5.4	34.1	5.2
Southern Branch								
SBA1	8/20/99	36.82549	76.29070	12.000	23.5	1.9	86.7	8.1
SBB1	8/20/99	36.81167	76.28861	1.000	19.8	4.7	34.6	10.9
SBC1	8/20/99	36.79935	76.29440	7.000	21	1.6	84.2	8.2
SBD1	8/20/99	36.77962	76.31058	11.000	21.3	1.5	67.4	6.7
SBD2	8/20/99	36.76675	76.29694	2.000	19	3.6	49.4	7.0
SBD4	8/27/99	36.74021	76.29909	1.000	17	2.7	7.8	1.2
Lafayette River								
LFA1	7/30/99	36.90918	76.31378	2.000	23.1	7.3	63.3	3.6
LFB1	7/30/99	36.88958	76.28303	3.000	21.2	5.5	99.1	7.8
Western Branch								
WBB1	8/13/99	36.84622	76.35761	1.000	23.2	6.9	92.3	6.0
WBB5	8/13/99	36.82926	76.39316	1.000	20.7	6.9	87.4	7.1
Eastern Branch								
EBB1	8/23/99	36.83778	76.24222	1.000	16.5	9.3	47.3	5.1

ATTACHMENT B

MUMMICHOG HISTOPATHOLOGY INVETIGATION

THE ELIZABETH RIVER MONITORING PROGRAM 1998-99: MUMMICHOG LIVER HISTOPATHOLOGY AS AN INDICATOR OF ENVIRONMENTAL QUALITY

A Final Report Submitted to

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Abstract

The Virginia Dept. of Environmental Quality recently initiated a long-term monitoring program of the heavily polluted Elizabeth River. The overall aim during year one of this program was to monitor water, sediment and biota for a baseline assessment of the river's "health". A specific objective was to evaluate potential adverse biological effects of chemical exposure in the indigenous biota of the river. To this end, we evaluated the occurrence of pathological changes in the non-migratory mummichog, *Fundulus heteroclitus*, as an indicator of chemical contaminant exposure. Sixty mummichog from each of 12 study sites within the system were processed by routine methods for histopathological analysis. Target tissues included liver, gill and kidney. Although direct comparisons between fish lesion prevalences and sediment chemical contaminant concentrations and sediment and water toxicity bioassays conducted as part of this program have not yet been made, we found a clear positive association between mummichog liver pathology and sediment polycyclic aromatic hydrocarbon (PAH) concentration data available from prior studies of the river. Liver alterations including pre-cancerous and cancerous lesions were found at highest prevalences in the most industrialized and heavily contaminated portions of the river, whereas lowest lesion prevalences occurred in the more residential, less contaminated stretches. Gill and kidney pathology attributable to chemical exposure was minimal in the fish evaluated and no clear associations with sediment chemical contamination could be demonstrated. This baseline study indicates that liver pathology observed in mummichog is the result of exposure to chemical contaminants in the environment. It also suggests that select liver lesions are useful bioindicators of local environmental quality and that these types of biological endpoints can be used to identify those portions of the Elizabeth River exhibiting the highest levels of environmental degradation. We would like to introduce this monitoring approach as a highly effective tool to track environmental recovery of specific habitats within the river following future remediation efforts.

Introduction

The Virginia Department of Environmental Quality (DEQ) has initiated a long-term environmental monitoring program of the Elizabeth River in Virginia. The overall aim of this program is to develop an initial assessment of the rivers "health" and to track the state of the watershed by implementation of a long-term ambient monitoring program for water, sediment and biota (Barbachem et al., 1997). A specific goal of this program is to evaluate adverse biological effects attributable to chemical exposure of the indigenous biota and to track environmental recovery over time as pollutant inputs are reduced and site-specific remediation efforts are advanced. This Final Report outlines the results of a study undertaken in the Elizabeth River during the fall of 1998 to evaluate the utility and applicability of selected histopathological endpoints in a pollution monitoring context.

Recent investigations by the Virginia Institute of Marine Science within the Elizabeth River indicate that the small, abundant and non-migratory mummichog (*Fundulus heteroclitus*) is an effective bio-indicator of adverse health effects attributable to pollutant exposure (Vogelbein et al., 1990, 1997,). Histologic endpoints (i.e. cytotoxic, pre-cancerous, cancerous and other liver lesions) have been used by us as indicators of the direct impacts of chemical contaminants on the health of these indigenous fish. Further, laboratory sediment exposures recently completed at VIMS, indicate that some of these liver pathologies (e.g. cancer) can be attributed directly to polycyclic aromatic hydrocarbon (PAH) exposure, with certain liver lesions exhibiting a clear positive correlation to total sediment PAH concentrations. Incorporation of fish tissue histopathology into the Elizabeth River Monitoring Program will therefore provide state managers with sound data on direct negative health impacts attributable to local chronic exposure of a native animal population. This non-migratory fish is an excellent integrator of contaminant exposure in localized restricted environments. Thus, the health of a given localized fish population in this case mirrors the "health" or quality of that populations immediate environment. This type of approach has in recent years been adapted by NOAA's National Status and Trends Program and by the EPA in some instances as well. NOAA is now vigorously pursuing the use of these types of data in litigation of select polluters. The objective of this study was to obtain an estimate of the health status of mummichogs from 12 sampling localities in the Elizabeth River by way of histopathological analysis of fish health.

The study described here aims to incorporate mummichog tissue histopathology into the long-term field monitoring program currently underway in the Elizabeth River. A preliminary spring 1998 study conducted under guidance and support by DEQ indicated that liver histopathological endpoints in this small fish species provide a simple and cost-effective measure of animal health and thus of local environmental quality. The present follow-up study further refines the use of liver pathologies in pollution monitoring and expands our observations and expertise to other tissues and organ systems.

Materials and Methods

Fish Collections: Field collections of mummichog from 12 study sites within the Elizabeth River were conducted on November 20, 23, and 24, 1998. Although it was late in the season and water temperatures were falling rapidly, we were able to obtain fish from eight of the 12 DEQ designated study sites. Fish were collected along the shore as near to the specific DEQ-designated stations as possible, in all cases within several hundred meters of the exact coordinates for the given stations. At 3 of the designated study sites we were unable to obtain fish. These Stations were either located in the open reaches (ER-C1) or in the most industrialized bulkheaded portions (ER-F1, SB-A1) of the river. No marshy shallow water habitat was found near these sites and mummichog were not present here. These three sites also yielded no fish during the Spring 1998 preliminary study. One study site in the Western Branch (WB-B5) had significant suitable habitat but we were unsuccessful in capturing mummichog there. However, this locality yielded fish during the spring preliminary study. The four study sites where fish were not obtained in this study were substituted with other localities within the Elizabeth River (see Table 1). We selected 3 sites from the southern branch of the River and provided them with station designations (SB-A2, SB-D3, SB-D5). These sites are noted in bold in Table 1. We also selected a substitute station within the near portion of the Eastern Branch of the River (designated EB-B2) in proximity to much of the shipbuilding activity associated with commercial and Naval shipyards located along this portion of the River. Specific coordinates for all of the study sites are provided in Table 1. The first set of Lat and Long coordinates is that provided by DEQ for each of the specific Study Sites. The second set of coordinates represents the actual locations where fish for this study were collected. Note that Station SB-B2 (15) is one that was added to the initial list of 11 stations. This site is within Scuffeltown Creek on the southern branch of the River. The last four sites listed in the Table are substitutions made by us to replace the four sites where we were unable to obtain fish. A total of 717 fish was collected over 3 days. All fish were successfully transported live to VIMS and were necropsied within 14 days of collection.

Fish Necropsy, Tissue Processing and Histologic evaluation: Just prior to necropsy, fish were anesthetized by overdose with a fish anesthetic (MS-222), inspected for grossly visible lesions, and weighed and measured (SL, TL). A mid ventral incision was made into the body cavity and the visceral organs were removed. The liver, the primary target organ for this study, was examined and any grossly visible lesions were noted and described. The liver was then dissected free from the other viscera, cut into 3-5 pieces, placed in an individually labeled tissue cassette, and transferred to Bouin's fixative. Spleens, head kidneys and gills were then dissected and fixed in Bouins fluid. Each fish received a unique specimen identification number and all data from that fish were entered onto a VIMS AADDL Fish Histopathology data sheet as a permanent record. Tissues were then processed for routine paraffin histology. All tissue samples were infiltrated with paraffin in a tissue processor (Shandon Hypercenter), embedded on a tissue embedding center (Fisher), sectioned at 5μm on a rotary microtome (Olympus, Cut 4055), stained with hematoxylin and eosin (H&E), and permanently mounted in Permount media.

Table 1. Lat/Long coordinates for Elizabeth River Study Sites where mummichog, *Fundulus heteroclitus*, were collected.

Station	Lat	Long	Fish Coll. Lat	Fish Coll Long	# Fish
ER-C1 (1)	36° 52' 54"	76° 20' 10"	----	----	No habitat
ER-F1 (3)	36° 50' 56"	76° 17' 54"	----	----	No habitat
LF-A1	36° 54' 30"	76° 18' 49"	36° 54.795'	76° 19.175'	60
LF-B1	36° 53' 21"	76° 16' 51"	36° 53.296'	76° 16.897'	60
WB-B1	36° 50' 38"	76° 21' 39"	36° 50.615'	76° 21.931'	60
WB-B5	36° 49' 30"	76° 23' 50"	36° 49.555'	76° 23.894'	No fish
SB-A1	36° 49' 38"	76° 17' 30"	----	----	No habitat
SB-B1	36° 48' 45"	76° 17' 27"	36° 48.464'	76° 17.641'	57
SB-D2	36° 45' 54"	76° 18' 00"	36° 45.838'	76° 18.836'	60
SB-D4	36° 44' 10"	76° 17' 42"	36° 44.483'	76° 18.133'	60
EB-B1	36° 50' 10"	76° 14' 45"	36° 50.375'	76° 14.937'	60
SB-B2	36° 48' 29"	76° 17' 15"	36° 48.475'	76° 17.018'	60
EB-B2*	Replacement Station		36° 50.217'	76° 16.417'	60
SB-A2	Replacement Station		36° 49.250'	76° 17.225'	60
SB-D3	Replacement Station		36° 47.647'	76° 17.433'	60
SB-D5	Replacement Station		36° 47.975'	76° 17.920'	60

* Stations in bold are assigned a new code based on the DEQ convention

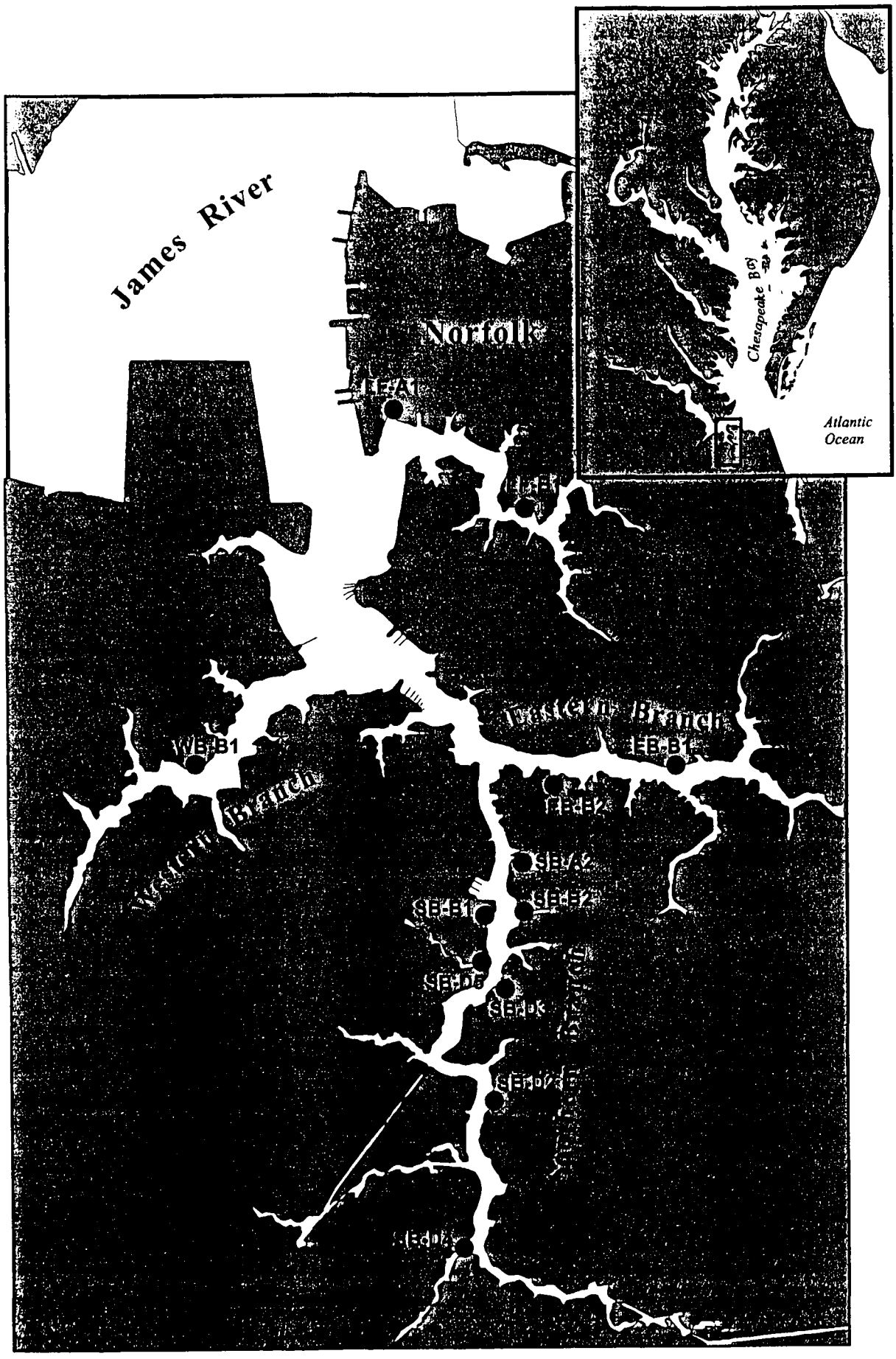

Figure 1. Mummichog (*Fundulus heteroclitus*) sampling stations for November 1998.

Histopathological Evaluation: Slides were evaluated microscopically by a fish pathologist (Zwerner/Vogelbein). All tissue lesions were noted onto a VIMS Histopathologic Diagnosis Record: Lesion Prevalence Data sheet (see Appendix A) and entered into a computer based data storage system. Results for a suite of liver lesions including neoplastic, degenerative/cytotoxic and parasitic changes were tabulated in order to calculate lesion prevalence data. Lesion diagnoses were based on criteria obtained from the literature on rodent pathology and on a liver lesion nomenclature for mummichog devised by us previously (Vogelbein et al., 1997). Additionally, lesion severity scores were calculated semi-quantitatively for the liver proliferative lesions as a group (altered hepatocellular foci and neoplasms) and for a suite of selected liver lesions indicative of sublethal liver cell cytotoxicity. A visual severity score was assigned based on the abundance and size of these lesions in the tissue sections. They were assigned the following scores: 0 - not present, 1- low occurrence and severity, 2 - moderate occurrence and severity, or 3 - high occurrence and severity. Results of these scores were tabulated and average liver lesion severity scores were calculated for the group of 57-60 fish from each of the 12 study sites.

Gills and kidneys have not been evaluated histologically on a routine basis in the past. Therefore, a specific goal of this study was to determine if toxicopathic lesions occurred in these tissues in mummichogs from the Elizabeth River. This aspect of the study was considerably more preliminary than the liver pathology in that we had no prior information on these tissues and did not know what to expect. Therefore, this report includes a preliminary characterization of, and a tentative nomenclature for, the lesions observed in these two organs. We also provide a preliminary evaluation of gill and kidney lesion prevalences for the 12 study sites. We stress however, that this work is not definitive and requires further refinement in future efforts. Additionally, we suggest that any evaluation of these lesions will benefit from quantitative morphometric analysis in the future.

Results

Fish Meristics

Total length and weight measurements for mummichog from 12 Elizabeth River study sites are presented in Figures 1 and 2 respectively. Mean total length ranged from about 50 - 93 mm, with the smallest fish captured at the two eastern branch study sites and the largest being caught at site SB-A2 off the southern branch of the river. Fish from site EB-B2 were significantly smaller (therefore assumed to be younger) than fish from the other sites and this needs to be taken into consideration when evaluating lesion prevalences, especially the chronic proliferative liver lesions. These lesions are known to occur at highest prevalences in the oldest and largest fish and it is significant that altered hepatocellular foci and hepatic neoplasms occurred in this group despite their significantly smaller size (see below).

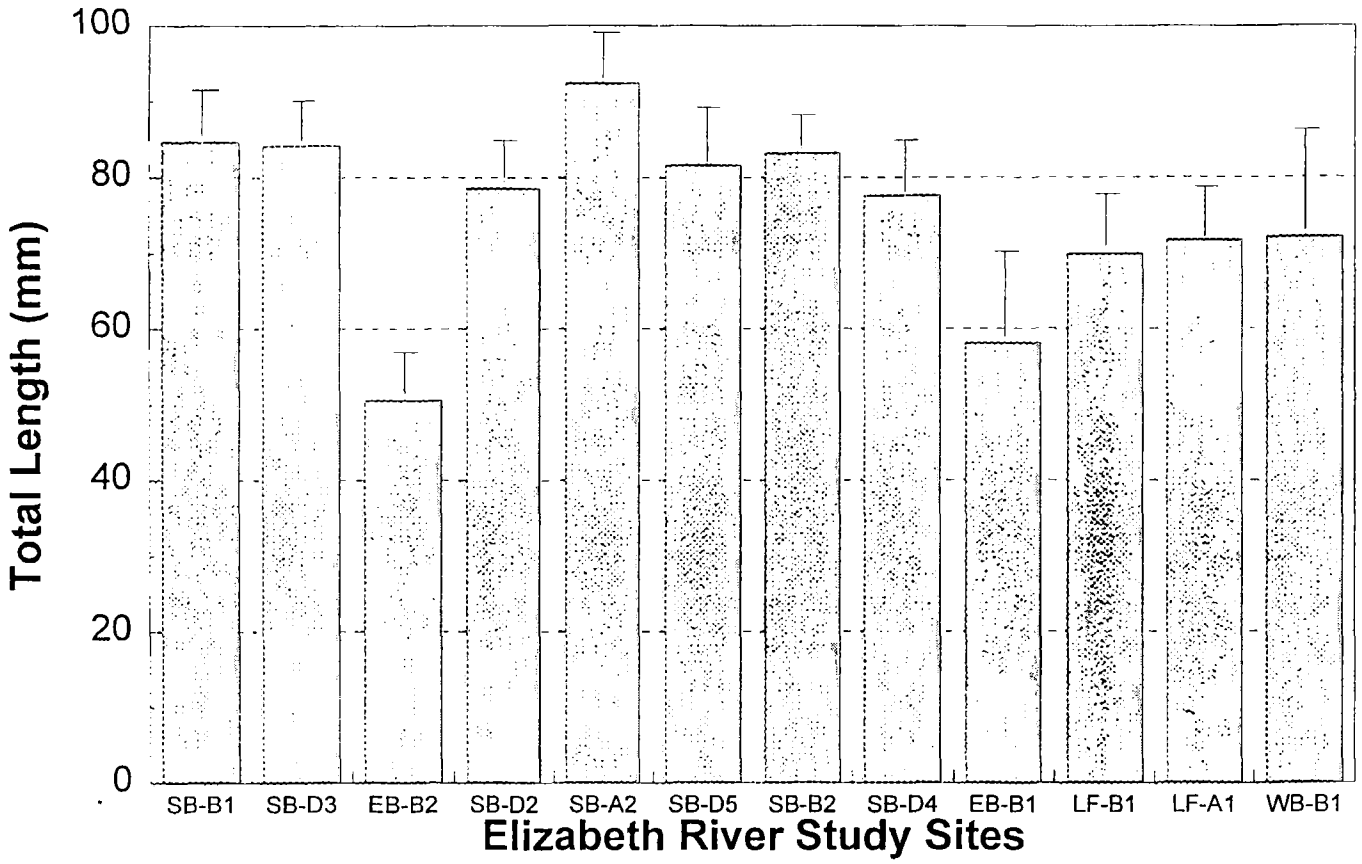

Figure 2. Mean total length (bar = std dev) of mummichogs (N=60) collected Nov, 1998 from 12 study sites in the Elizabeth River, Virginia

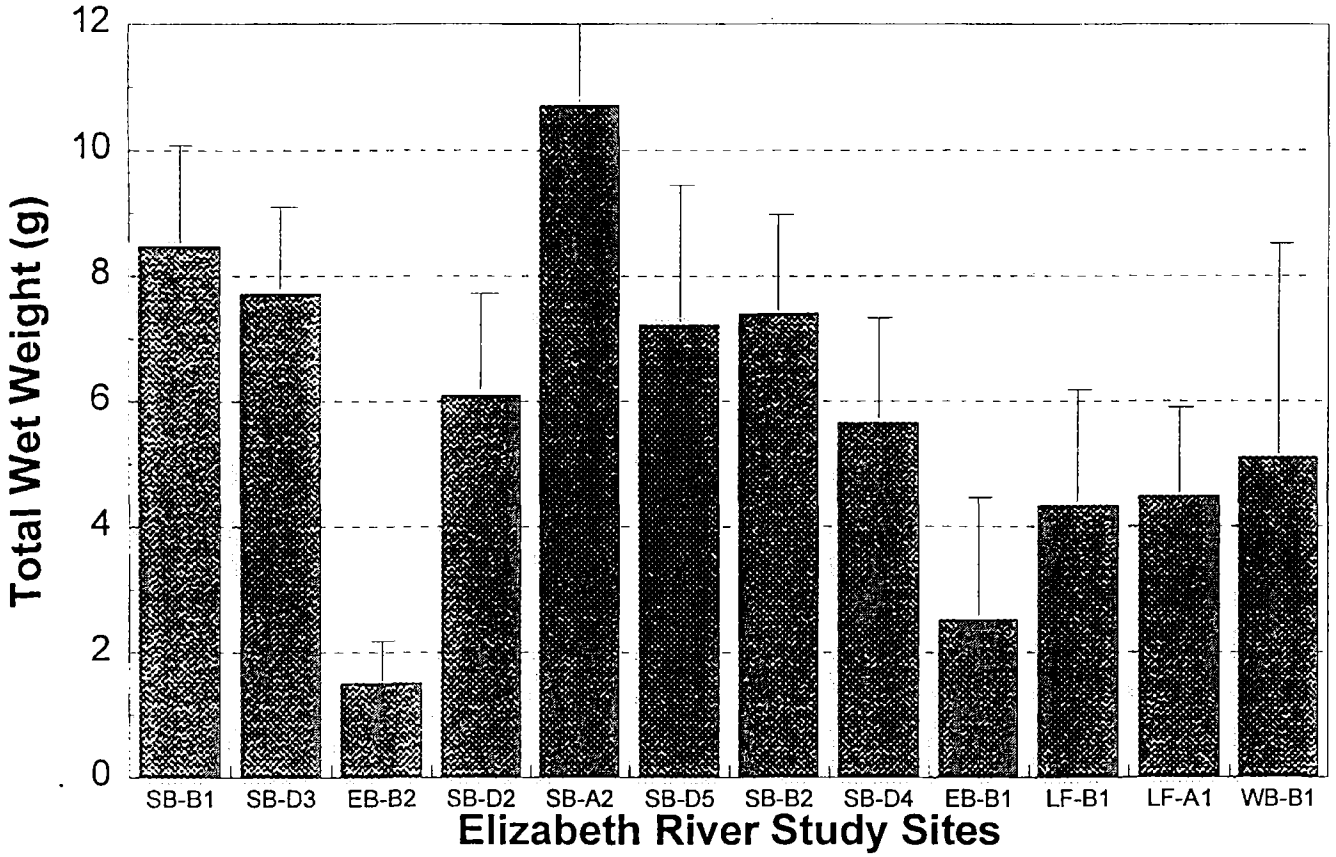

Figure 3. Mean total wet weight (bar = std dev) of mummichogs (N=60) collected Nov, 1998 from 12 study sites in the Elizabeth River, Virginia.

Liver Histology and Lesion Epizootiology

Microscopic appearance of selected liver lesions observed during this study have been illustrated previously (Vogelbein et al, 1990; 1997; Vogelbein, 1998) and the reader is referred to those studies. A general classification system based on histomorphologic criteria has been devised by us for the spectrum of toxicopathic liver lesions observed in mummichog inhabiting a creosote-contaminated site in the southern branch of the Elizabeth River (Vogelben et al., 1990; 1993). This classification system is also used in this study. Lesions included in this scheme arise predominantly in the liver and morphologically resemble the changes that develop in rodents and fishes following laboratory exposure to potent hepatotoxic and hepato-carcinogenic compounds. The spectrum of changes previously observed in the mummichog includes: **1)** lesions considered to be indicative of hepatotoxicity (eg. degenerative hepatocellular changes, reactive/inflammatory lesions, and intracellular storage disorders); **2)** proliferative lesions presumably of hepatocytic origin (altered hepatocellular foci, hepatic neoplasms, and related lesions); and **3)** proliferative lesions deriving from cells other than hepatocytes (biliary, vascular, pancreatic, and lymphoid hyperplastic lesions and neoplasms). Lesions belonging to the last category were not seen in this study. This classification scheme is evolving and continues to be refined as we gain a better understanding of toxicant-induced liver disease in this species. A detailed understanding of lesion morphology is essential if these changes are to be used as endpoints of adverse biological effects in fishes inhabiting chemically contaminated environments. Descriptions of the normal mummichog liver structure and the predominent non-neoplastic and neoplastic hepatic lesions observed in this study are provided below.

Normal Liver Structure

Normal liver structure in the mummichog is similar to that described for other teleosts (e.g. Hinton et al., 1972; Hampton et al., 1985; 1988; 1989) and consists of branched, anastomosing hepatic tubules lined by the hepatic sinusoids). Hepatocytes are monomorphic, with heterochromatic nuclei of a uniform shape and size. Nuclei are spherical and generally have one prominent centric nucleolus. Cytoplasmic staining and vacuolation of hepatocytes varies among fish but is homogeneous within individual livers. Macrophage aggregates (MA) are generally very small, present in low numbers, and mostly associated with exocine pancreatic tissues and the hepatic vasculature.

Cytotoxic Liver Lesion Histology

Hepatic Megalocytosis: This lesion is characterized by the presence of greatly enlarged, highly pleomorphic hepatocytes with atypical, sometimes bizarre, hyperchromatic nuclei. Its distribution is focal or diffuse. The cytoplasm of affected cells is often eosinophilic and fibrillar and may contain irregularly-shaped basophilic inclusions as well as hyaline and ceroid. Larger areas of affected cells may also include single cell necrosis. This lesion is similar to what has been reported in other fishes where it is considered to be a specific degenerative

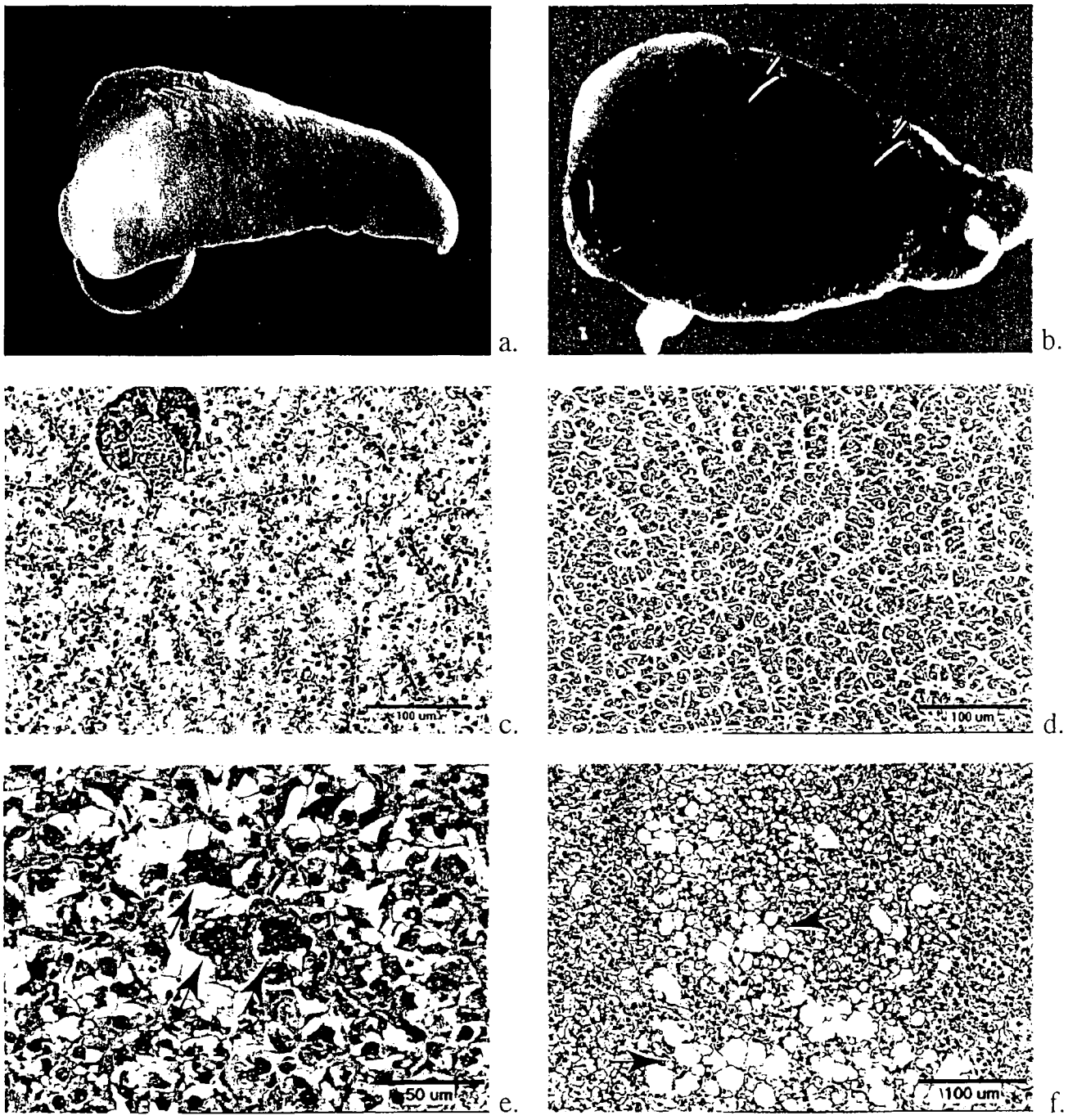

Plate 1. Gross and histologic appearance of liver tissue in the mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Gross appearance of normal liver. Note homogeneous appearance in color and texture. b) Gross appearance of liver in a fish from study site SB-B1 (adjacent to the Atlantic Wood facility). Arrows: cancerous lesions. c) Histology of normal mummichog liver (male). d) Histology of normal mummichog liver (female). e) Hepatic megalocytosis. Arrows: megalocytic liver cells. f) Fatty change. Arrows: liver cells containing large vacuoles due to fat storage.

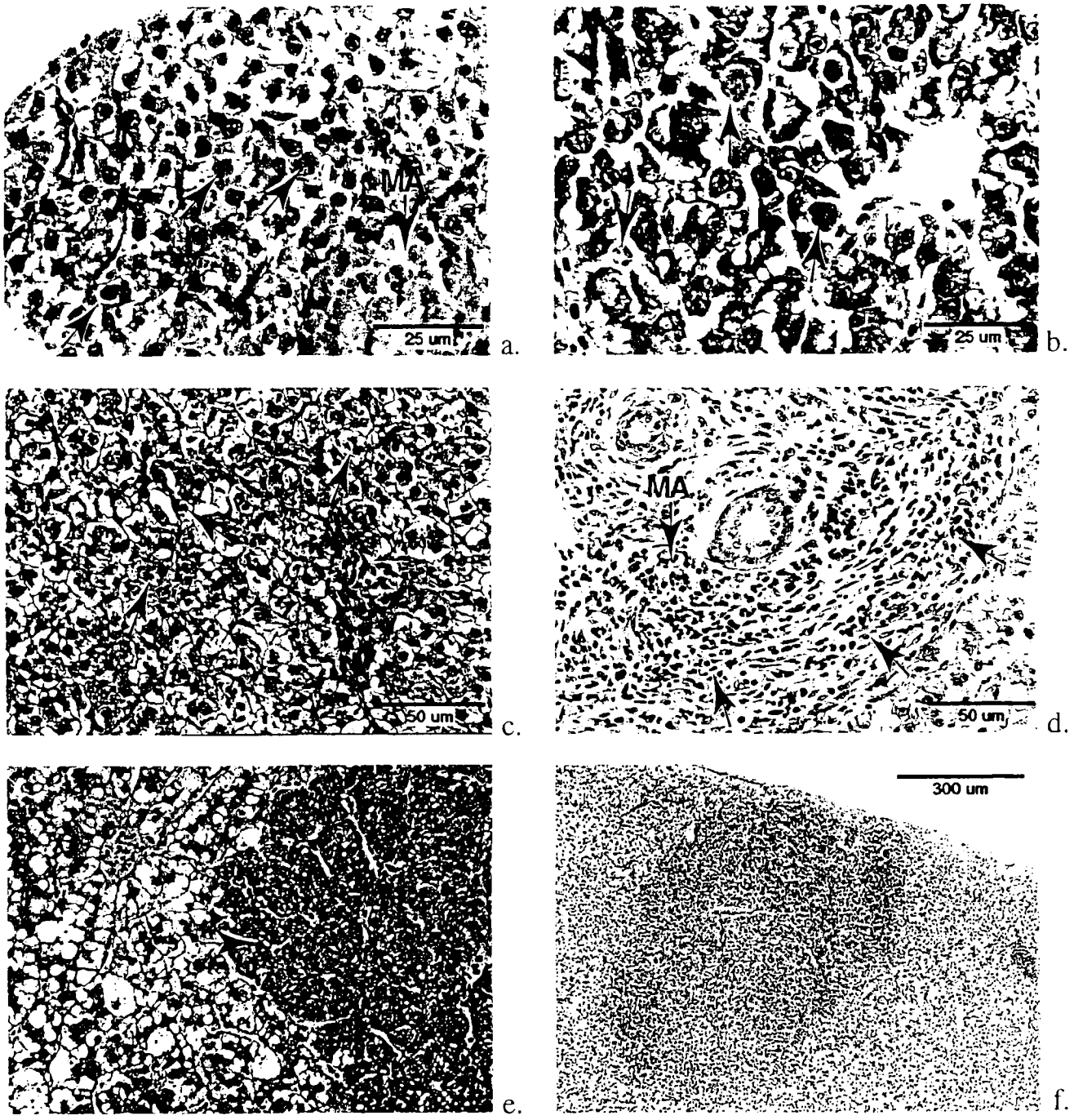

Plate 2. Pathological alterations in liver of mummichog from study site SB-B1. a) Hyaline change. Arrows: eosinophilic hyaline droplets within liver cells. MA: macrophage aggregate. b) Single cell necrosis (apoptosis). Arrows: single dead hepatocytes exhibiting nuclear remnants. c) Hepatocellular ceroidosis. Arrows: brown ceroid granules within cytoplasm of hepatocytes. d) Non-specific inflammation surrounding two bile ductules. Arrows: accumulations of inflammatory cells. MA: macrophage aggregate. e) Altered hepatocellular focus, basophilic phenotype (Arrow). f) Altered hepatocellular focus, eosinophilic phenotype (type 1) (Arrow).

lesion associated with exposure to toxicants (Myers et al., 1987; Hinton, 1993; Stephen et al., 1993).

Nuclear Atypia: This lesion is characterized by the occurrence of atypical nuclear morphology of hepatic parenchymal cells, including heterogeneity in nuclear size and shape and the occurrence of multiple nucleoli. This condition has a diffuse distribution within the hepatic parenchyma and its significance with respect to contaminant exposure in fishes is not clear.

Fatty Change: This condition is characterized by a diffuse distribution of hepatocytes, each containing one large or several smaller clear, smooth-edged lipid vacuoles that often displace the nucleus to the cell periphery. Unlike the vacuolated cell focus, from which this condition is distinguished, the affected cells in fatty change are not contiguous and may alternate with unaffected hepatocytes, sometimes forming elongated collections or tracts of affected cells. Hinton (1993) also distinguishes between focal fatty vacuolation and diffuse fatty change. Diffuse fatty change, although seen following exposure to a variety of hepatotoxic agents, also occurs in species that normally store abundant lipids and is influenced by nutritional as well as reproductive status. Although Hinton (1993) presently excludes diffuse fatty change as a viable biomarker, we prefer to take note of this condition until we have a better understanding of it in the mummichog and the factors that influence it.

Hepatocellular Ceroidosis: This condition is characterized by the deposition of yellow-brown, refractile, irregularly shaped pigment granules within the hepatocyte cytoplasm. This pigment is sudanophilic, acid-fast, PAS-positive, and iron negative and therefore probably lipogenic (ceroid/lipofuscin). Ceroid is also often found inside free macrophages and is the predominant pigment sequestered within macrophage aggregates (MA: see below). Our ultrastructural studies indicate that these granules are large heterogeneous residual bodies representing the end stage of an intracellular digestion process. Although this nonspecific condition has been observed in fish affected by nutritional deficiency, the presence of intra-hepatocytic ceroid in the mummichog is currently interpreted as an indication of sublethal cytotoxicity.

Hyaline Change: Hyaline change is characterized by the presence of large, homogenous, eosinophilic, glass-like inclusions located within degenerating hepatocytes or in the extracellular space. Hyaline bodies vary greatly in size, may be focally or diffusely distributed in degenerating liver tissue associated with other degenerative conditions such as ceroidosis, diffuse fatty change, and single cell necrosis, and can also occur in foci of cellular alteration. We currently interpret this condition to be a cellular degeneration that is similar to hyaline bodies associated with degenerative/nonspecific necrosis in the English sole by Myers et al. (1987).

Single Cell Necrosis: This condition is characterized by single, round or oval, intensely eosinophilic, rarely basophilic, bodies that are currently interpreted as dead hepatic parenchymal cells. These bodies are about the diameter of a hepatocyte or smaller, and contain small basophilic chromatin remnants. In the mummichog, single cell necrosis is most

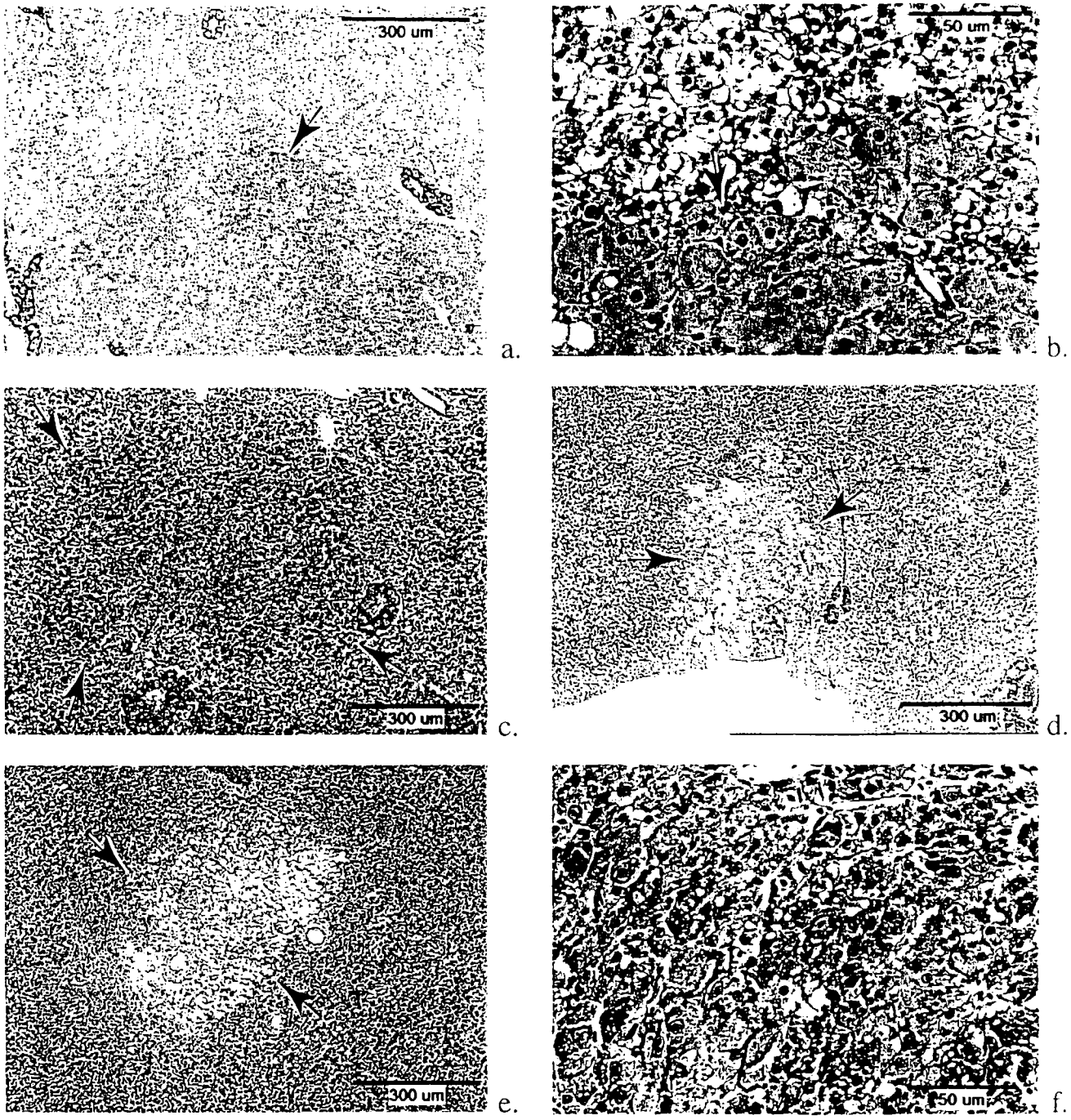

Plate 3. Pathological alterations in liver of mummichog from study site SB-B1. a) Altered hepatocellular focus, eosinophilic phenotype (type 2) (Arrow). b) Higher magnification of eosinophilic focus in Fig. 3a illustrating the greatly hypertrophied liver cells within the focus (arrow). c) Altered hepatocellular focus, amphophilic phenotype (arrows). d) Altered hepatocellular focus, clear cell phenotype (arrows). e) Altered hepatocellular focus, vacuolated cell phenotype (arrows). f) Closeup of altered hepatocellular focus, mixed cell phenotype. Note presence of eosinophilic and basophilic cells.

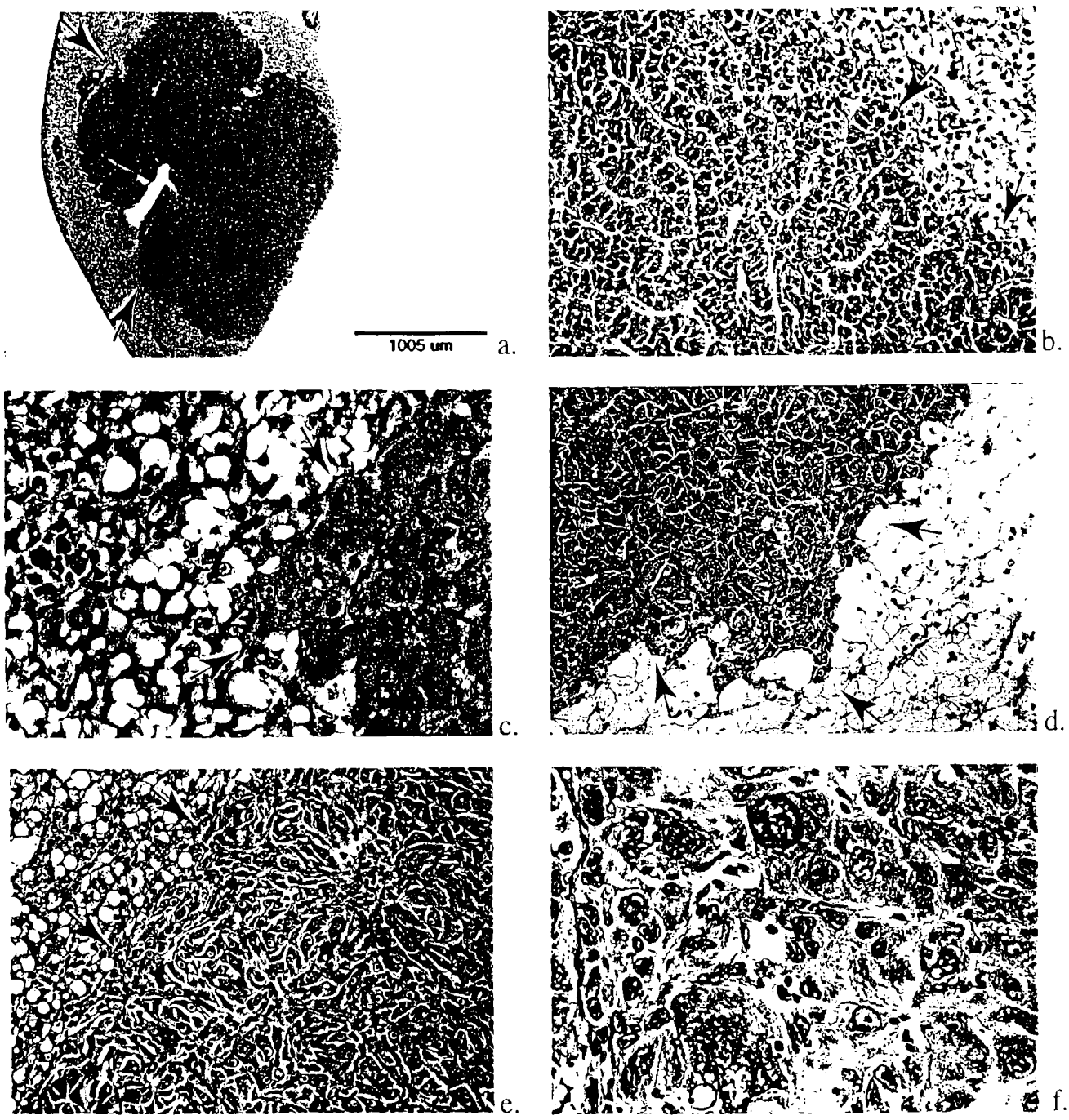

Plate 4. Pathological alterations in liver of mummichog from study site SB-B1.
a) Hepatocellular adenoma (arrows). b) Closeup of Fig. 4a showing distinct border of the neoplasm (arrows). c) Early (small) hepatocellular carcinoma (arrows). d) Advanced hepatocellular carcinoma exhibiting locally invasive border (arrows). e) Advanced anaplastic hepatocellular carcinoma (arrows). f) Closeup showing cellular detail of advanced anaplastic hepatocellular carcinoma.

often distributed diffusely and often accompanies other degenerative changes such as ceroidosis, diffuse fatty change, and hyaline change. We therefore consider this lesion to be a non-specific necrotic condition that is indicative of exposure to hepatotoxic agents, and currently prefer to distinguish it from apoptosis, or normal scheduled cell death.

Macrophage Aggregates: Macrophage aggregates are focal aggregations of macrophages replete with pale tan to black pigments. The predominant pigments sequestered are lipogenic (ceroid/lipofuscin). Macrophage aggregates are surrounded by a fine capsule of connective tissue, are often associated with sites of inflammation, and, in mummichog from contaminated habitats, are greatly elevated in number and in size. In the liver they most frequently occur in close association with the hepatic portal tracts. The role of macrophage aggregates is controversial and the reasons for their increase in size and number in fish from contaminated habitats are not well understood (Wolke, 1992). We currently classify this condition as the terminal stage of a reactive/inflammatory process in response to the specific and non-specific degenerative necrotic changes occurring in the livers of toxicant-exposed mummichog.

Inflammation: This condition is characterized by the presence of focal aggregations of leukocytes, usually in close association with the hepatic vasculature and exocrine pancreatic tissues. Leukocytes comprising these lesions are mixed, including both granulocytes and agranular mononuclear cells. This lesion is presently interpreted as a cellular inflammatory response to the specific and non-specific degenerative changes described above, and represents an attempt by the fish to sequester and remove cellular debris resulting from those degenerative pathological conditions. Inflammatory lesions associated with visible infections are excluded.

Prevalence Data for Cytotoxic Liver Lesions

Lesion prevalence data for selected cytotoxic liver lesions in mummichog from 12 study sites are summarized in figures 3 & 4. Several of these lesions occurred at high prevalences in the more industrialized portions of the river but exhibited significantly lower prevalences at the less industrialized more residential portions of the system (e.g. CER, MA). Several other lesions exhibited a downward trend when the more industrialized, potentially more contaminated sites were compared with the more residential portions of the river (e.g. NA, FAT, SCN). The remaining lesions evaluated were either rare or did not exhibit any trends (e.g. HMC, HYA).

Hepatic Neoplasms and Related Lesions

Altered Hepatocellular Foci: The histologic morphology of these pre-neoplastic liver lesions has been described previously (Vogelbein et al., 1990, 1997). Currently we distingush between seven phenotypic variants: two histologically distinct eosinophilic foci; the basophilic focus; the amphophilic focus; the clear cell focus; the vacuolated cell focus; and the mixed cell focus. These focal lesions have been experimentally induced in laboratory rodents (Frith and Ward, 1980; Steward et al., 1980; Maronpot,et al., 1986) and fishes (Hawkins et al., 1985;

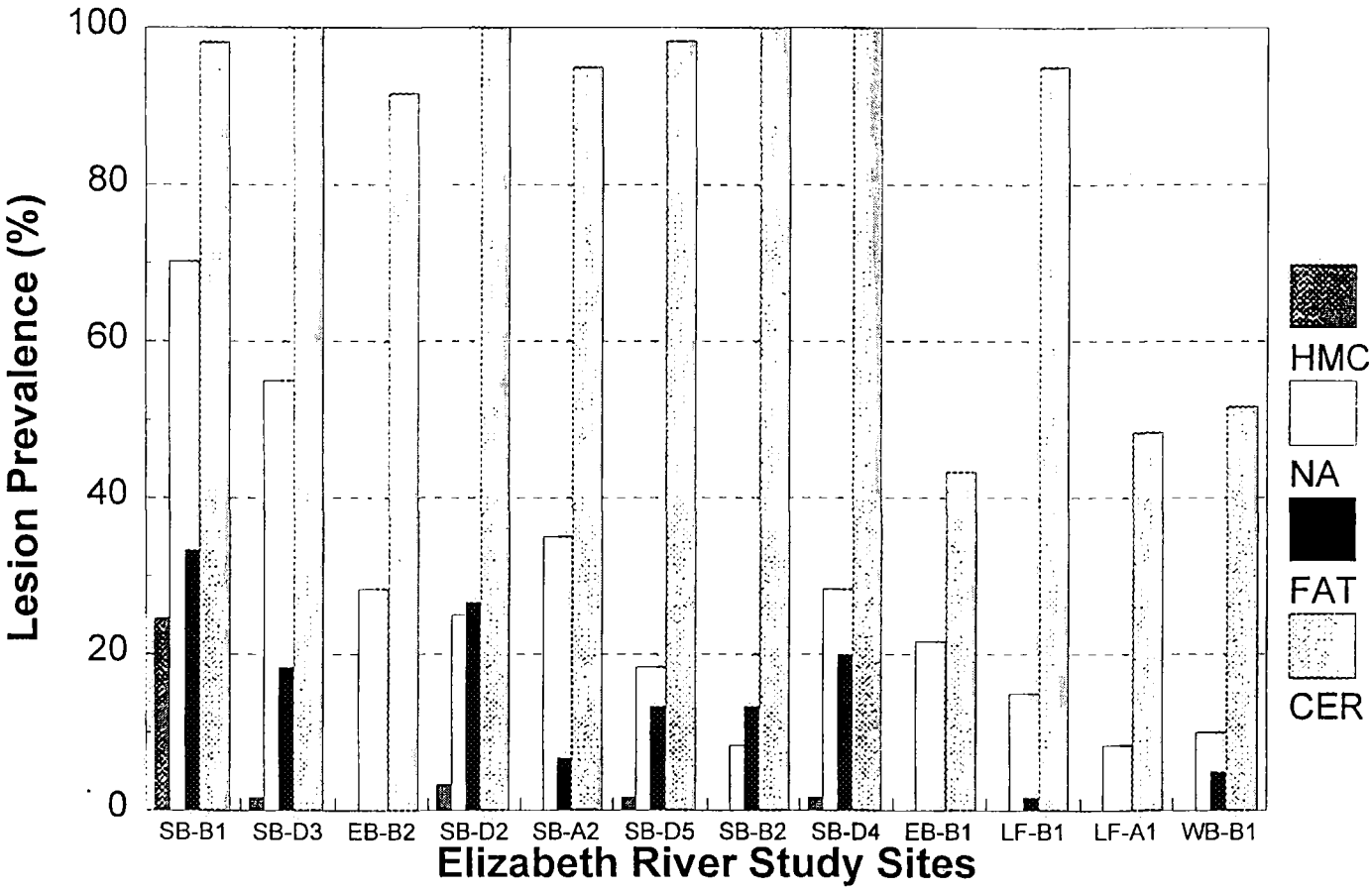

Figure 4. Prevalence data for cytotoxic liver lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. HMC: hepatic megalocytosis, NA: nuclear atypia, FAT: fatty change, CER: hepatocellular ceroidosis.

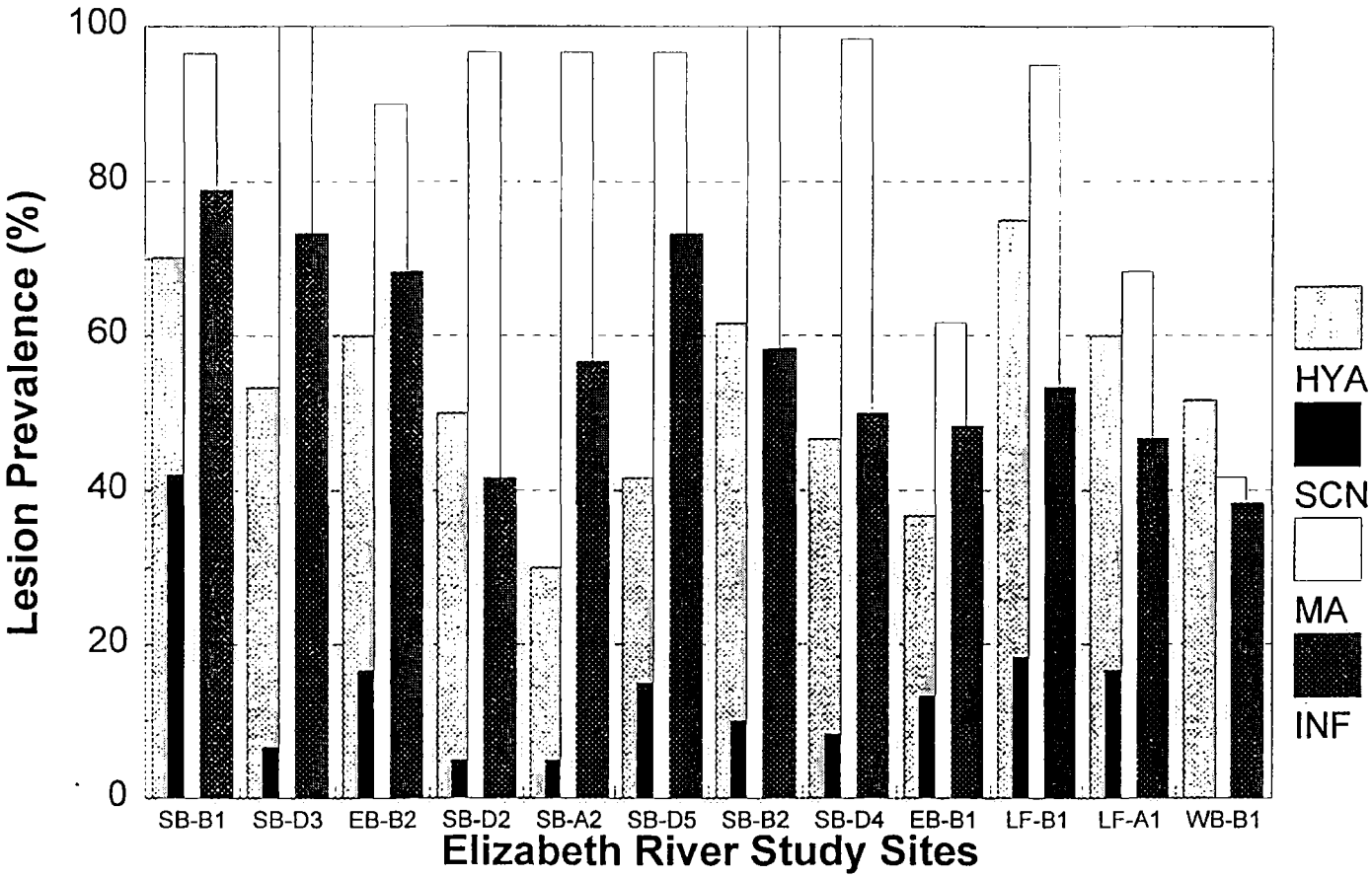

Figure 5. Prevalence data for cytotoxic liver lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. HYA: hyaline change, SCN: single cell necrosis, MA: macrophage aggregates, INF: inflammation.

Hendricks et al., 1984; Couch & Courtney, 1987; Hinton and Lauren, 1990a, 1990b; Hinton et al.,1992) by exposure to potent chemical carinogens and are considered to be an early stage in the histogenesis of liver cancer. They also occur in a variety of fishes inhabiting polluted aquatic habitats (Pierce et al., 1978; Smith et al., 1979; Murchelano and Wolke, 1985, 1991; Malins et al., 1987a; Vogelbein et al., 1990; Myers et al., 1993) and are considered to be effective, meaningful biomarkers of toxicant (carcinogen) exposure in wild fish populations (Hinton, 1993). In the mummichog, we currently consider all of these phenotypes to be pre-neoplastic with the potential for progression to liver cell adenoma and hepatocellular carcinoma. Evidence supporting this view includes our frequent observation of "foci-in-foci", especially in mummichog from study site SB-B1. This lesion is an altered focus in which another focus of less well-differentiated hepatocytes arises. Often these cell populations exhibit the cytologic features of liver cell adenoma or hepatocellular carcinoma. This is in contrast to aflatoxin exposed rainbow trout, *Oncorhynchus mykiss,* in which the eosinophilic focus is not thought to progress on to carcinoma (Hendricks et al., 1984). The lesion we currently identify as a clear cell focus may differ from the typical clear cell focus described in rodents and other fishes. This lesion is typically thought of as being enriched in glycogen (e.g. Bannasch et al., 1982; 1989; Hinton, 1993). In the mummichog this lesion contains elevated levels of both glycogen and of lipid, and differs from the vacuolated cell focus by having multiple lipid droplets that are microvesicular (unpublished ultrastructural observations). We currently prefer to view these as distinct lesions until more detailed morphological studies are completed.

Hepatocellular Neoplasms: Histomorphologic features of hepatic neoplasms (HN) in the mummichog have been described previously (Vogelbein et al., 1990; 1997). Liver cell adenomas (ADN) are relatively rare in the mummichog. These are large, nodular, well-differentiated lesions that exhibit some compression along at least part of their border and often cause the liver capsule to bulge. They cause great diagnostic difficulties in AW mummichog because many intermediate lesion types (some exhibiting features of both Af as well as adenomas or carcinomas) co-occur with them. Hepatocellular carcinomas ranged from very well to poorly differentiated. For this study we scored small (early) hepatocellular carcinomas (EHC) and large advanced carcinomas (AHC) separately because of distinct seasonal differences in these lesion categories in prior studies. Adenomas and carcinomas in the mummichog exhibit eosinophilic, basophilic, and amphophilic phenotypes, with the basophilic variant being the most common. Several undifferentiated hepatocellular neoplasms arising within carcinomas have been diagnosed as hepatoblastomas in previous studies. These lesions closely resemble the hepatoblastomas described in mice and humans (Nonoyama et al., 1988; Gonzalez-Crussi et al.,1982) and are characterized by small undifferentiated embryonal hepatocytes forming rosettes and pseudotubules. A striking feature of these tumors is an extremely high mitotic index. Our recent ultrastructural studies indicate that the cells comprising these neoplasms form bile canaliculi, supporting the diagnosis of hepatoblastoma. This rare neoplasm was not observed during this investigation. Although evidence remains largely circumstantial, there is general agreement among investigators that hepatic neoplasms (adenomas and carcinomas) and related hyperplastic liver lesions (altered foci) in fishes inhabiting industrialized aquatic environments are strongly correlated with exposure to

xenobiotic chemical contaminants (e.g. Baumann, 1989; Harshbarger and Clark, 1990; Malins et al., 1988; Myers et al., 1987; 1993; Vogelbein et al., 1990; 1994; 1997; Hinton, 1993). These field investigations and the numerous laboratory exposures of fishes using carcinogenic agents (cited above) support the application of these lesions as effective biomarkers of exposure to carcinogenic compounds in the aqueous environment and as indicators of environmental quality (Hinton et al., 1992; Hinton, 1993).

Prevalence Data for Altered Hepatocellular Foci and Hepatic Neoplasms

Individual lesion prevalences for 7 phenotypic variants of altered hepatocellular foci (AF) occurring in mummichog from 12 study sites are illustrated in Figures 5 and 6. The most commonly occurring altered hepatocellular foci were the eosinophilic focus Type 1, the basophilic focus and the clear cell focus. Highest lesion prevalences were observed at sites SB-B1 and SB-D3 located in the most heavily industrialized portion of the Elizabeth River. Lowest lesion prevalences and lesion diversity occurred at sites more distant from the industrialized portions of the river such as SB-D4, EB-B1, LF-A1, LF-B1 and WB-B1. Strong, biologically significant differences are evident between the study sites, with prevalences of altered foci spanning a range from 1.7 to 85% (e.g. Fig. 5). A similar trend is evident for the hepatic neoplasms (Figure 7), with extremely high prevalences of adenomas and carcinomas occurring at sites SB-B1 and SB-D3, low prevalences for these lesions at sites EB-B2, SB-D2 and SB-A2, and their abscence from the remaining study sites. Total altered hepatocellular foci and total hepatic neoplasm prevalences (e.g. the percentage of fish exhibiting any one of the several phenotypes of altered focus or hepatic neoplasm) are summarized for the 12 study sites in Figure 8. When total lesion prevalences are evaluated, the differences in the response of mummichog at our 12 study sites are even more pronounced, with sites SB-B1, SB-D3 strongly impacted, sites EB-B2, SB-D2, and SB-A2 showing a clear negative impact, and the remaining sites only mildly affected or not affected at all.

Liver Lesion Severity Indices

Visually scored Lesion Severity Indices for the cytotoxic liver lesions and the hepatic proliferative lesions are presented in Figure 9. Both scores exhibit a range of values, with highest values occurring in fish from portions of the heavily industrialized southern and eastern branches of the river known to be near sources of significant contaminant inputs (SB-B1, SB-D3, SB-D2, and EB-B2). Lowest values were observed at the stations more distant from these areas of activity and in the more residential portions of the system (LF-A1, LF-B1, WB-B1, EB-B1, SB-D4). The trend in lesion severity scores across the 12 study sites is similar to the trend exhibited by lesion prevalences but was most pronounced for the hepatic proliferative lesions, with biologically significant differences in scores among the study sites.

Infectious Disease Agents in Liver

Prevalences of infectious disease agents in liver of mummichogsare presented in Fig. 10.

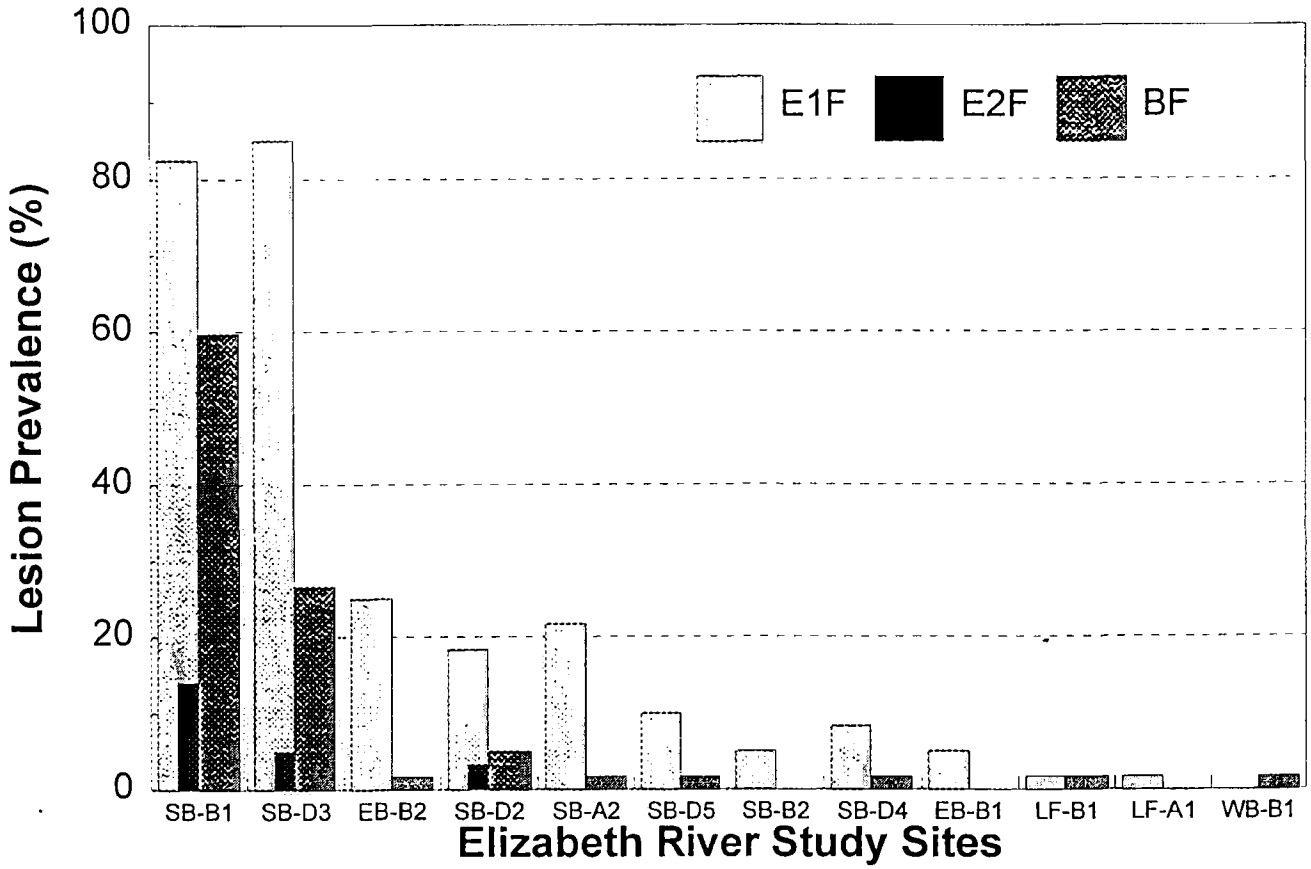

Figure 6. Prevalence values for specific altered hepatocellular foci in mummichogs collected Nov 1998 at 12 study sites in the Elizabeth River, Virginia. E1F: eosinophilic focus Type I, E2F: eosinophilic focus Type II, BF: basophilic focus.

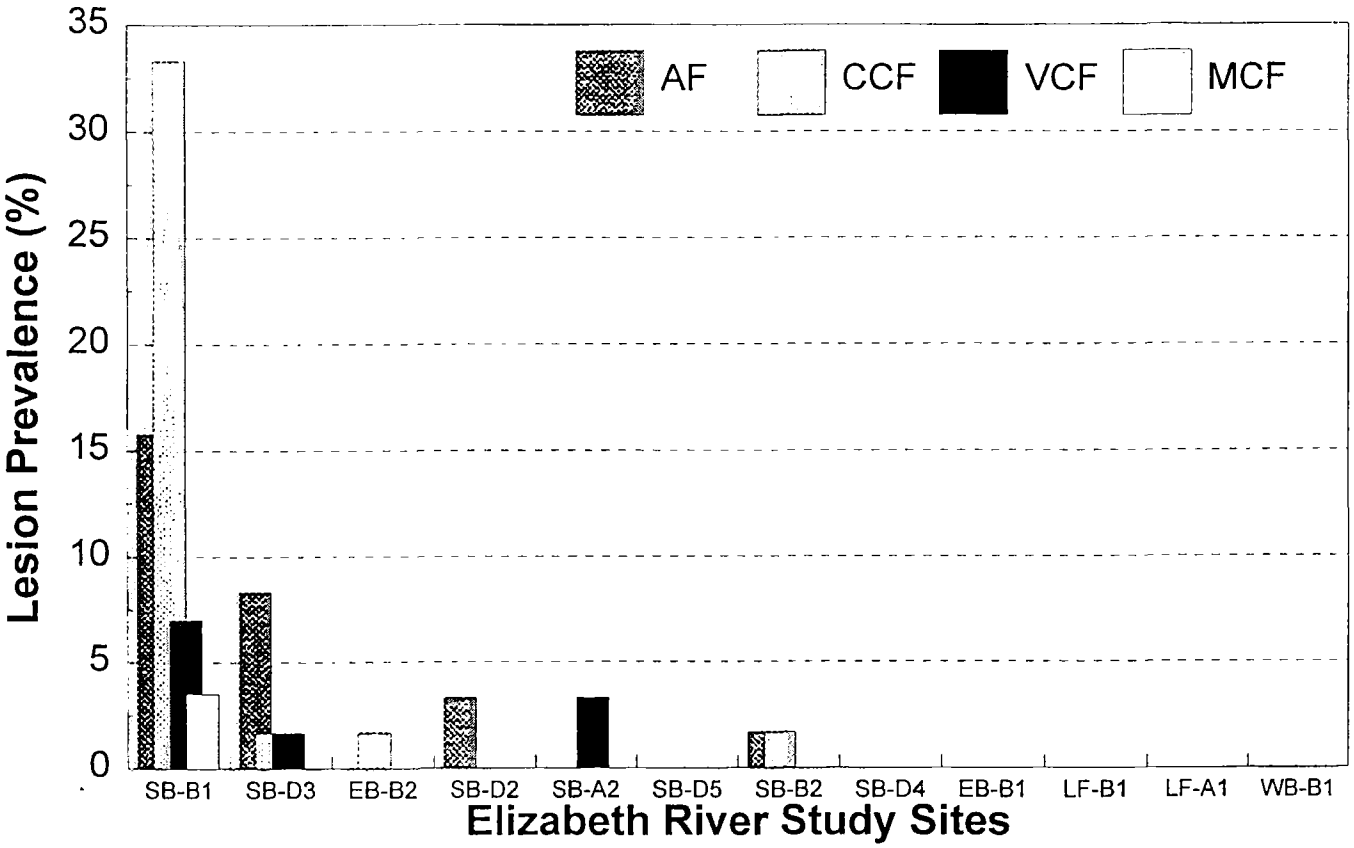

Figure 7. Prevalence values for specifi altered hepatocellular foci in mummichogs collected Nov 1998 at 12 study sites in the Elizabeth River, Virginia. AF: amphofilic focus, CCF: clear cell focus, VCF: vacuolated cell focus, MCF: mixed cell focus.

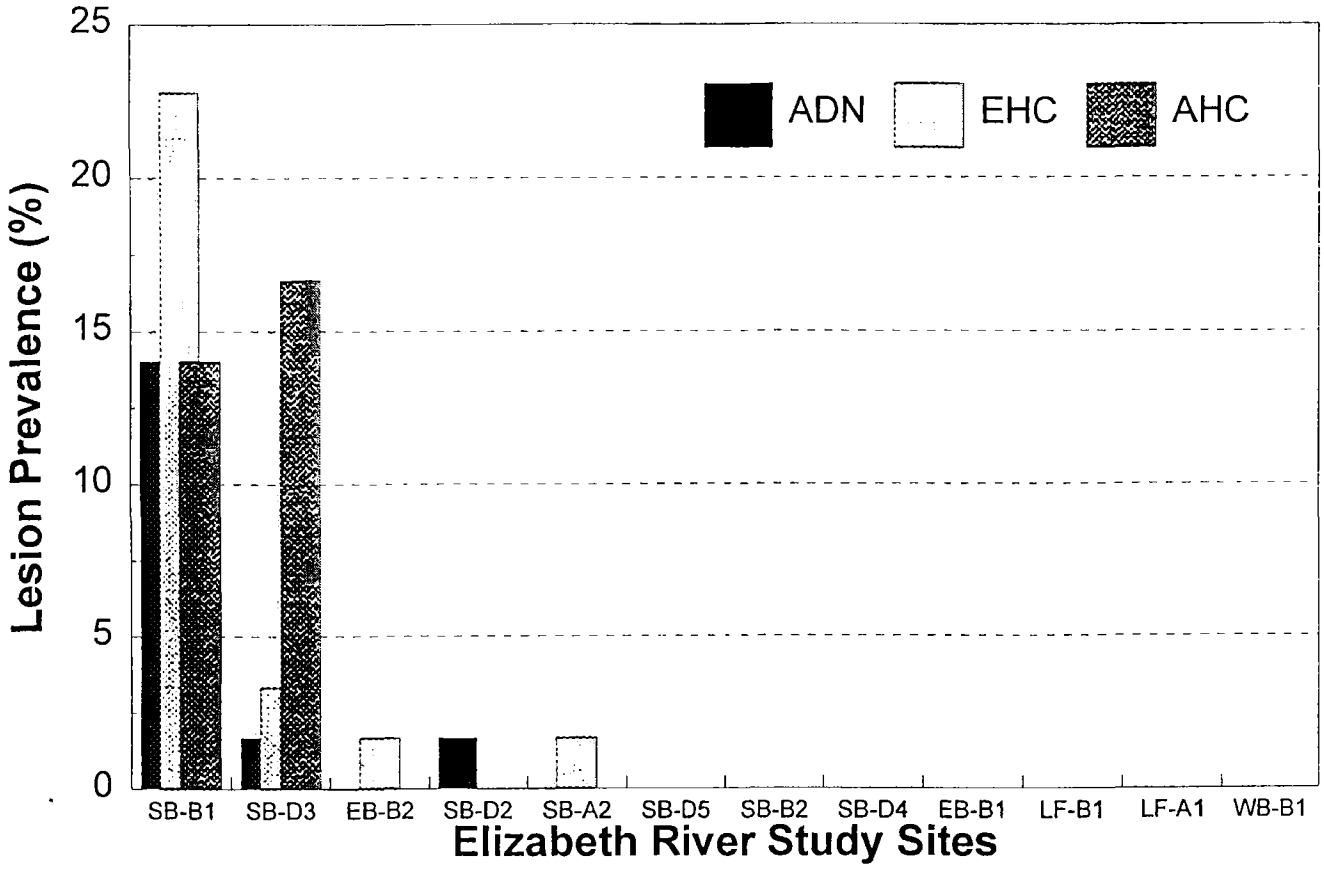

Figure 8. Neoplasm prevalence values for mummichogs collected Nov 1998 at 12 study sites in the Elizabeth River, Virginia. ADN: hepatocellular adenoma, EHC: early (small) hepatocellular carcinoma, AHC: advanced (large) hepatocellular carcinoma.

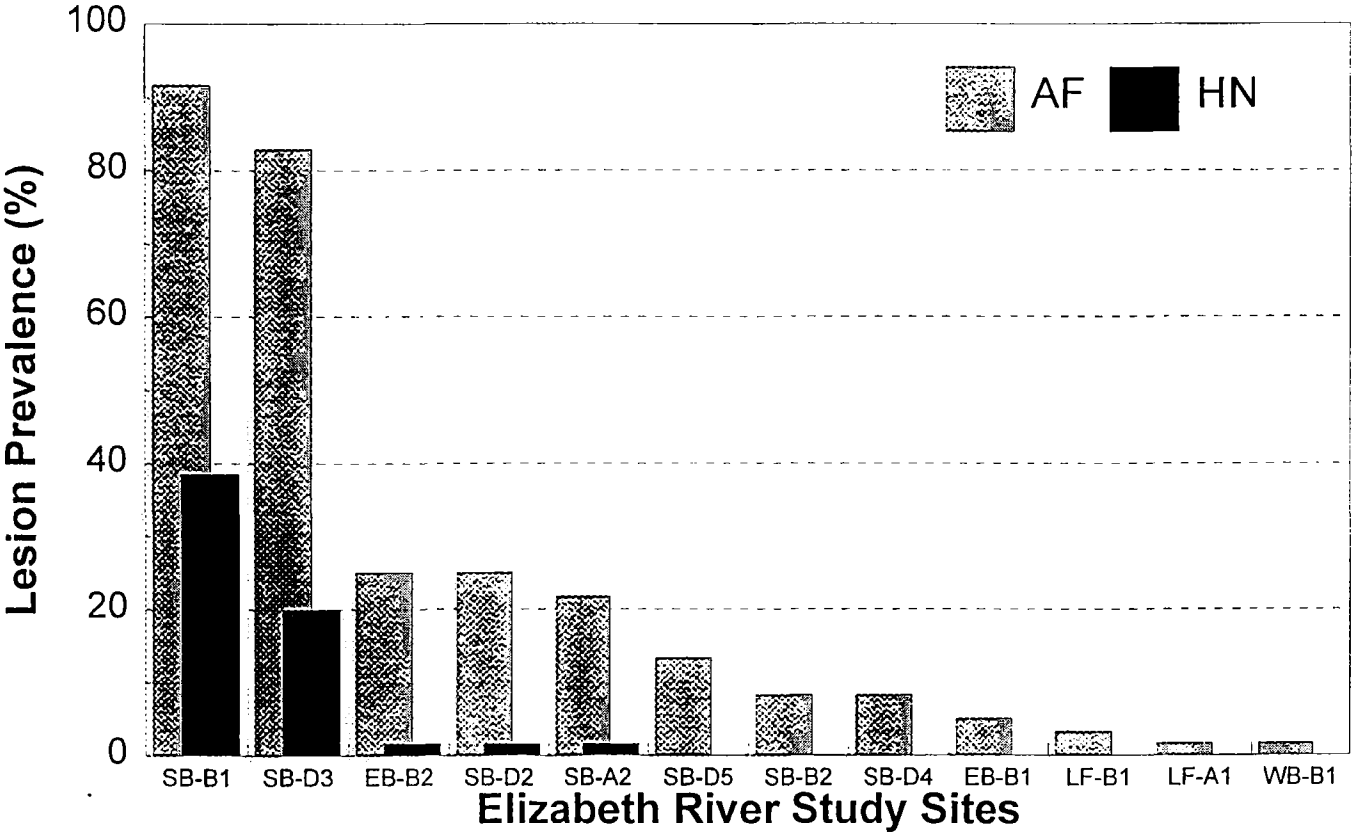

Figure 9. Total proliferative liver lesions in mummichogs (N = 60/site) collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. AF = total altered hepatocellular focus, HN = total hepatic neoplasm.

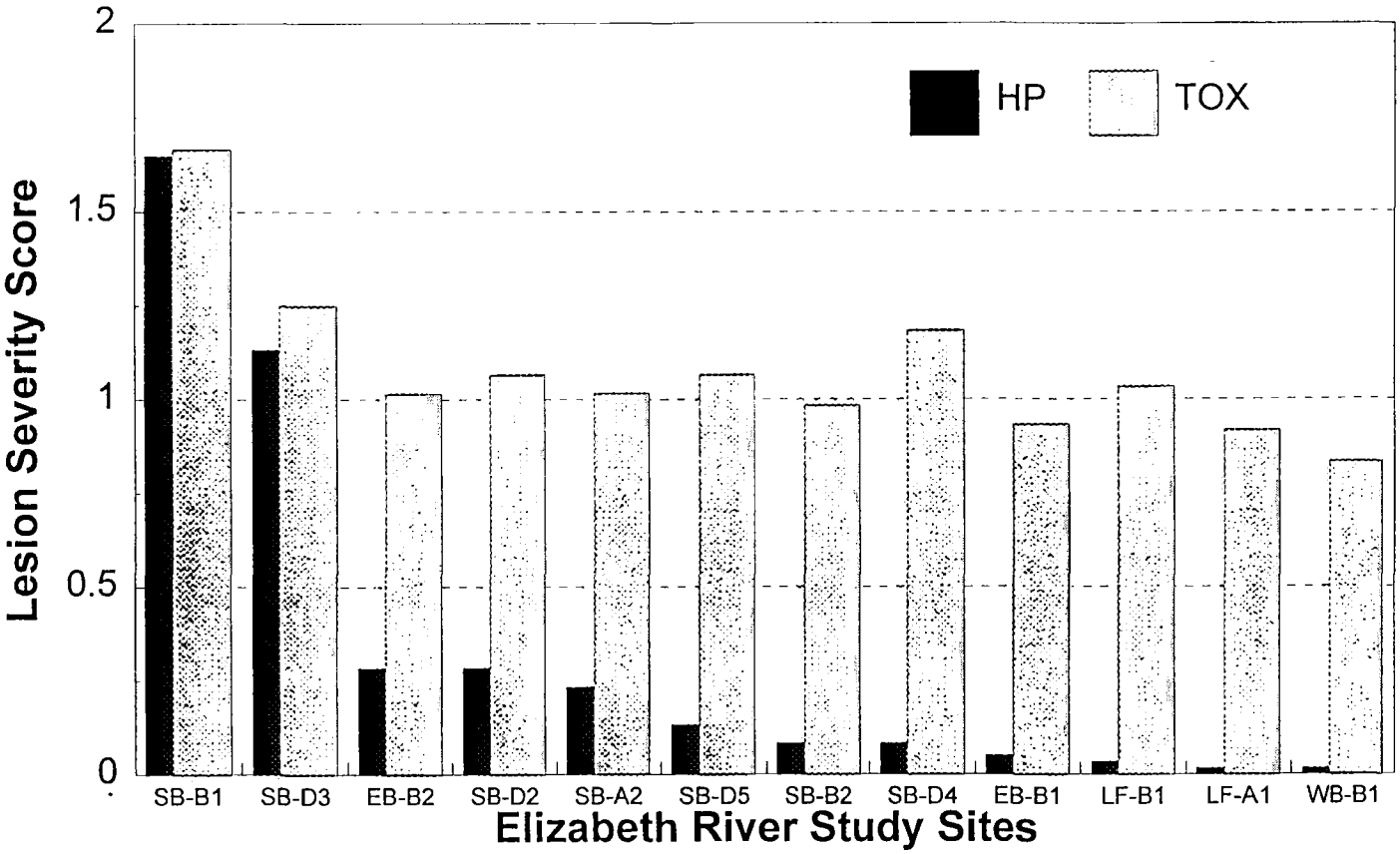

Figure 10. Liver lesions Severity indices for mummichog collected Nov 1998 at 12 study sites in the Elizabeth River, Virginia. HP: hepatic proliferative lesions, TOX: cytotoxic liver lesions.

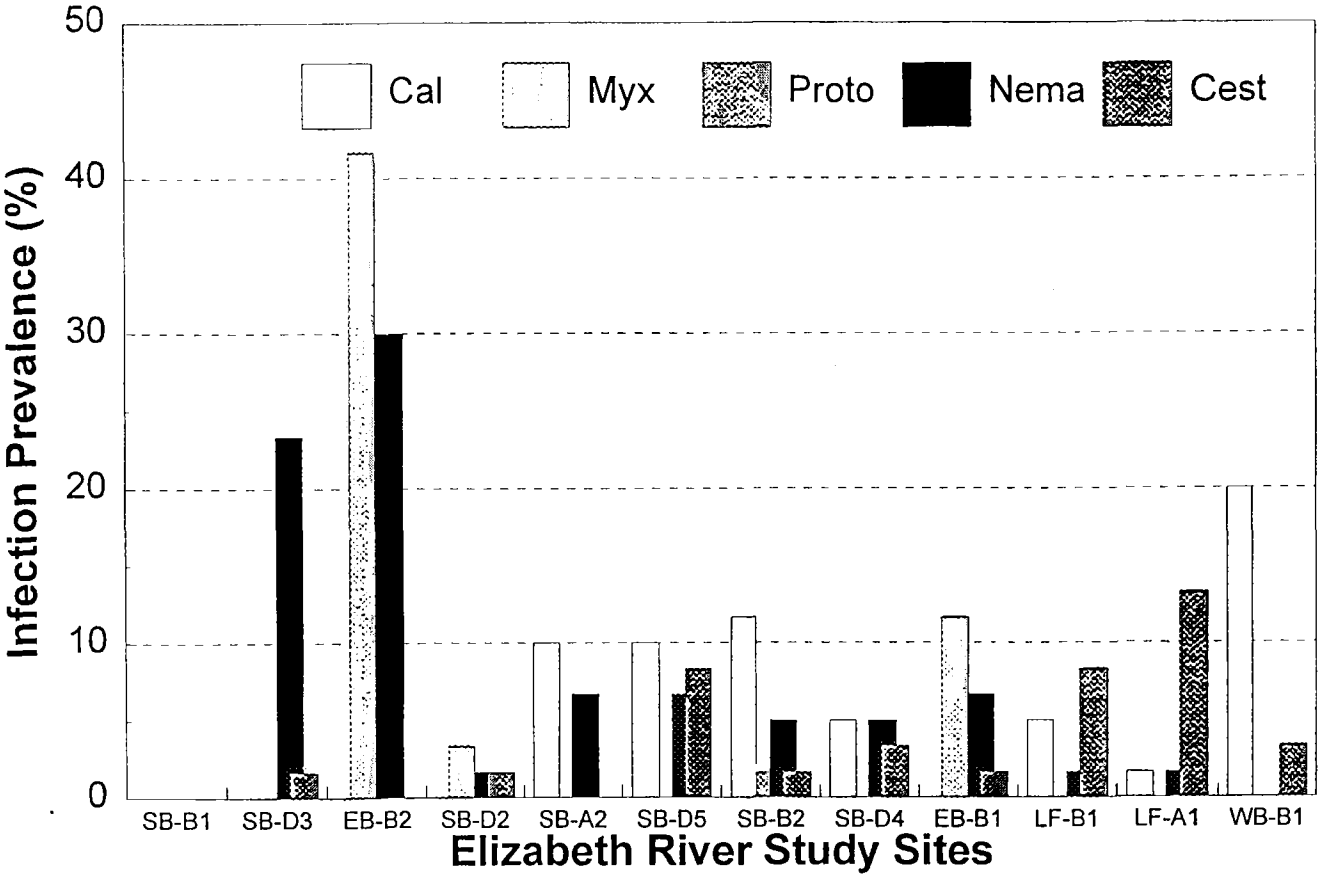

Figure 11. Prevalence of infectious disease agents in liver of mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. CAL: Calyptospora funduli, MYX: Myxidium sp., PROTO: other protozoan infection, NEMA: nematode infection, CEST: cestode infection.

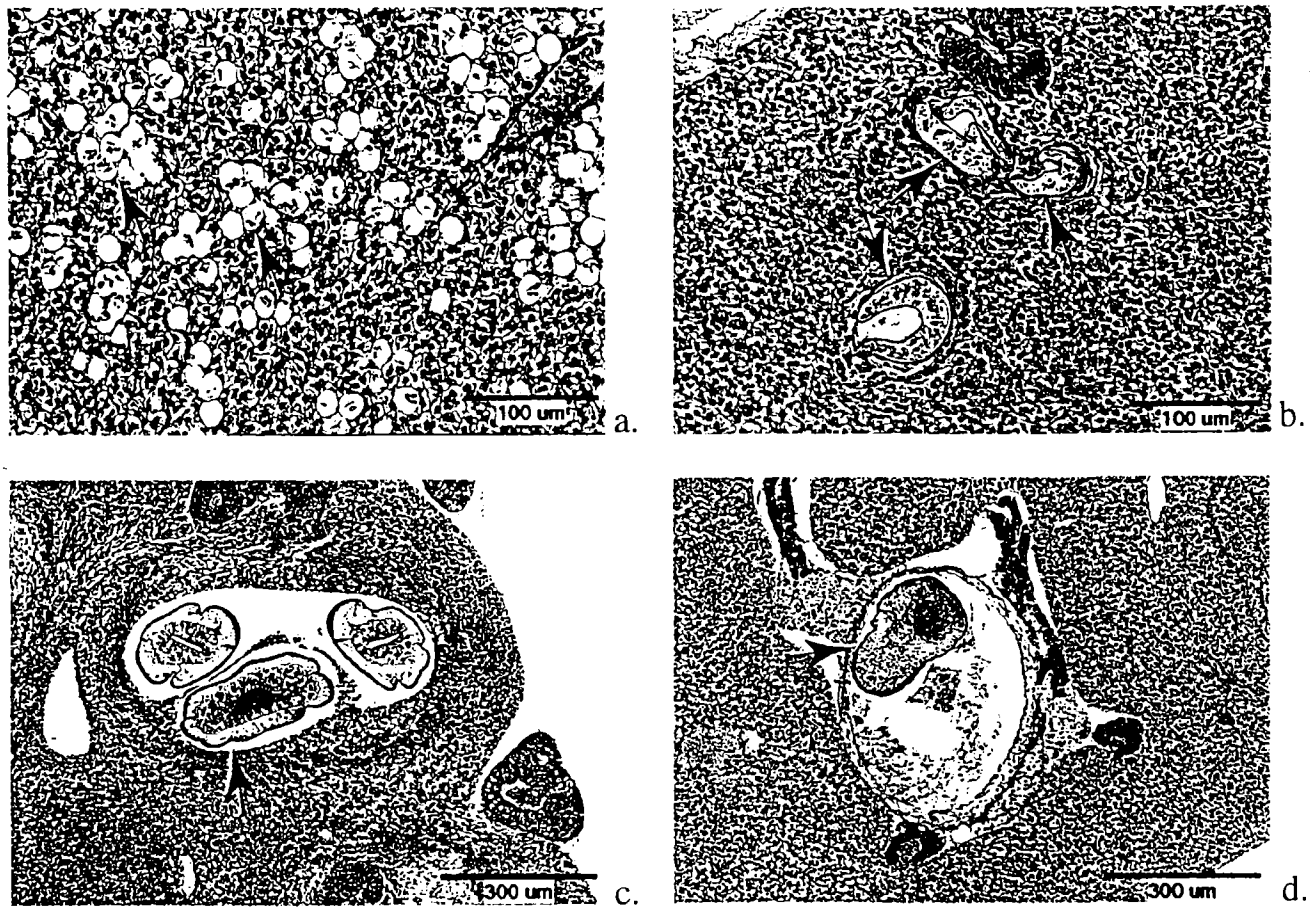

Plate 5. Parasitic infections in liver of mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Oocysts of the coccidian parasite, *Calyptospora funduli* (arrows). b) Trophozoites of the Myxosporidian, *Myxidium* sp. In the bile ducts (arrows). c) Parasitic nematode infection of liver tissue (arrow). d) Larval cestode (tapeworm) infection of liver (arrow).

No clear trends were apparent in these data, however, no parasites were observed in fish from site SB-B1 and high prevalences of *Myxidium* sp. and a nematode infection were observed at sites SB-D3 and EB-B2.

Gill Histology and Lesion Epizootiology

Normal Gill Structure

Gill tissues have never been routinely evaluated by us in a pollution monitoring context. We therefore briefly illustrate and describe normal mummichog gill structure and the common pathological alterations that we encountered in this study. Gill tissues in the mummichog consist of eight gill arches which are composed of cartilaginous supportive tissue. Numerous primary gill filaments arise from the gill arches and form a dense water filtering meshwork. A portion of a single gill filament is illustrated in Plate 1a. From the lateral surfaces of the gill filaments arise numerous delicate secondary gill lamellae, the structure of which is illustrated for three in Plate 1b. The secondary lamellae represent the site of gaseous exchange with the water. They are comprised externally of a delicate simple squamous epithelium that is supported by scant connective tissue and rests above a single layer of specialized vascular tissue spaces (Plate 1b) formed by Pilaster (Pillar) cells. Blood flows through these vascular channels in a counter-current flow regime to the direction of water flow along the outside of the lamellar surface. Gill tissue at the base of the secondary lamellae is rich in mucus secreting goblet cells and chloride cells.

Proliferative Gill Lesions

Branched Primary Filament: Branching of a primary gill filament is illustrated in Plate 1c. Morphology of the branching filament may be entirely normal or may exhibit increased cellularity due to proliferation of gill epithelium and inflammation. The specific cause for this condition is unknown.

Gill Hyperplasia: Hyperplasia of gill tissue is a non-specific proliferative response elicited by many different types of insults including chemical exposure, poor water quality (elevated ammonia and nitrite concentration), irritation cause by infectious disease agents including bacteria, protozoa and metazoan parasites, physical trauma etc. If severe, hyperplasia can result in fusion of adjacent primary gill filaments (e.g. Plate 1d), clubbing of distal gill filament tips (Plate 1e, f) with associated severe inflammation, and loss of functional respiratory surface area by obliteration of the secondary lamellae (Plate 2a, b). Mild hyperplasia can result in clubbing and deformation of individual lamellae (Plate 2c, d) and partial filling in of the space between secondary lamellae Plate 2a, c).

Vascular Proliferations: Several vascular proliferative lesions were observed in the gills of mummichogs from this study. These lesions resemble the vascular neoplasms and proliferative lesions reported previously in liver of mummichog from the Elizabeth River (Vogelbein et al.,

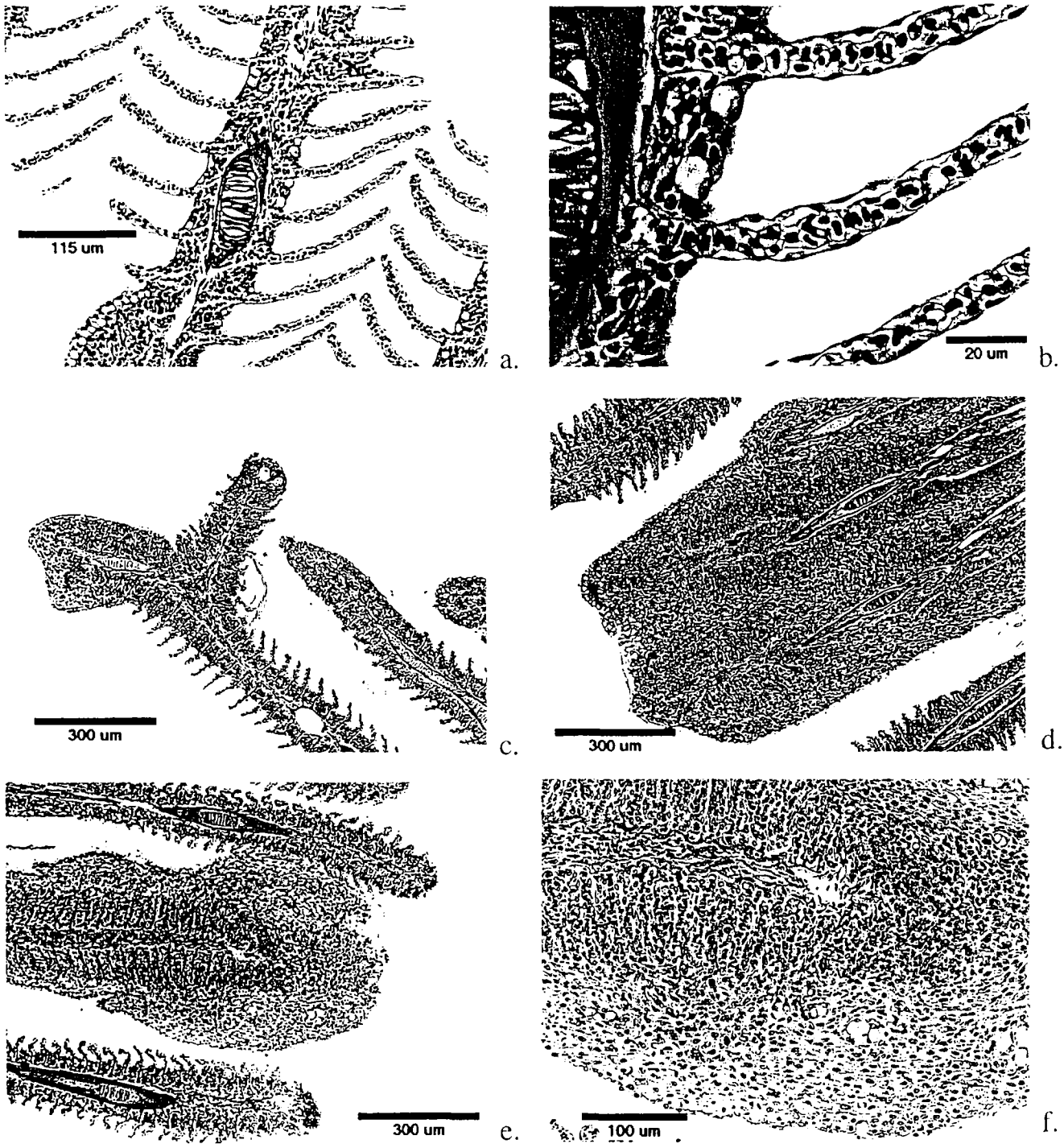

Plate 6. Normal gill structure and pathological alterations in the mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Normal gill structure showing a primary gill filament and numerous secondary gill lamellae. b) Higher magnification of Fig. a showing secondary lamellar structure. c) Branched primary gill filament. d) Hyperplasia and fusion of several gill filaments. e) Hyperplasia of distal gill filament tip. f) Higher magnification of figure e showing cell proliferation and inflammation

1997). These lesions appear comprised of proliferating endothelial cells (cells that line the inside of blood vessels) that often form vascular channels or spaces filled with blood (Plate 4a, b). Most of the lesions observed in gill were small and involved single secondary lamellae (Plate 4c, d). It is possible that the hyperplastic and neoplastic vascular lesions of the gill are caused by exposure to chemical contaminants in the environment. This has been suggested to be the case for these types of lesions developing in the liver of Elizabeth River mummichogs (Vogelbein et al., 1997).

Degenerative Gill Lesions

Lamellar Epithelial Detachment: This alteration is illustrated in Plate 3a. It is unclear if this is a pathological change or if it is an artifact of chemical fixation. But the condition presents as a separation of the respiratory epithelium of the secondary lamellae from the underlying (vascular) pillar cells, creating a clear space. This space may or may not contain a fibrinous homogeneous eosinophilic substance in varying amounts. Until we have a better understanding of this morphological alteration and its cause we will take note of it in our pathological evaluations of mummichog gill pathology.

Lamellar Hyaline Deposition: This condition is illustrated in Plate 3b and presents as an accumulation of dense hyaline eosinophilic material accumulating in the distal tips of the secondary lamellae. Often red blood cells are trapped within this material. This condition sometimes accompanies lamellar hyperplasia.

Telangiectasia: This condition is illustrated in Plate 3c and presents as a distension or swelling of secondary lamellae and congestion of the swollen lamella with blood. As with Lamellar epithelial detachment, it is presently unclear whether this condition is a pathological alteration or an artifact of fixation. Until we have a better understanding of its significance we will continue to take note of this condition.

Thrombosis: This condition is illustrated in Plate 3d. It presents as a prominent swelling of the secondary lamella with accumulation of an eosinophilic fibrinous clot containing inflammatory cells. This condition sometimes accompanies gill hyperplasia.

Infectious Disease Agents

Infectious disease agents are common in the gills of mummichog but in this study diversity was relatively low. Plate 5a illustrates attachment of a parasitic copepod to the distal tip of a gill filament. Plate 5b illustrates a Myxosporidan infection in the wall of a gill filament. Plates 5c & d illustrate an *Epitheliocystis* sp. infection. Plate 5e illustrates the encysted metacercarial stage of a digenetic trematode parasite. This is probably the most common parasitic infection of the gill in Elizabeth River mummichog. Plate 5f illustrates the attachment site of a monogenetic trematode, probably *Gyrodactylus* sp. This parasitic flatworm has a direct life cycle and can proliferate rapidly in closed culture systems leading to

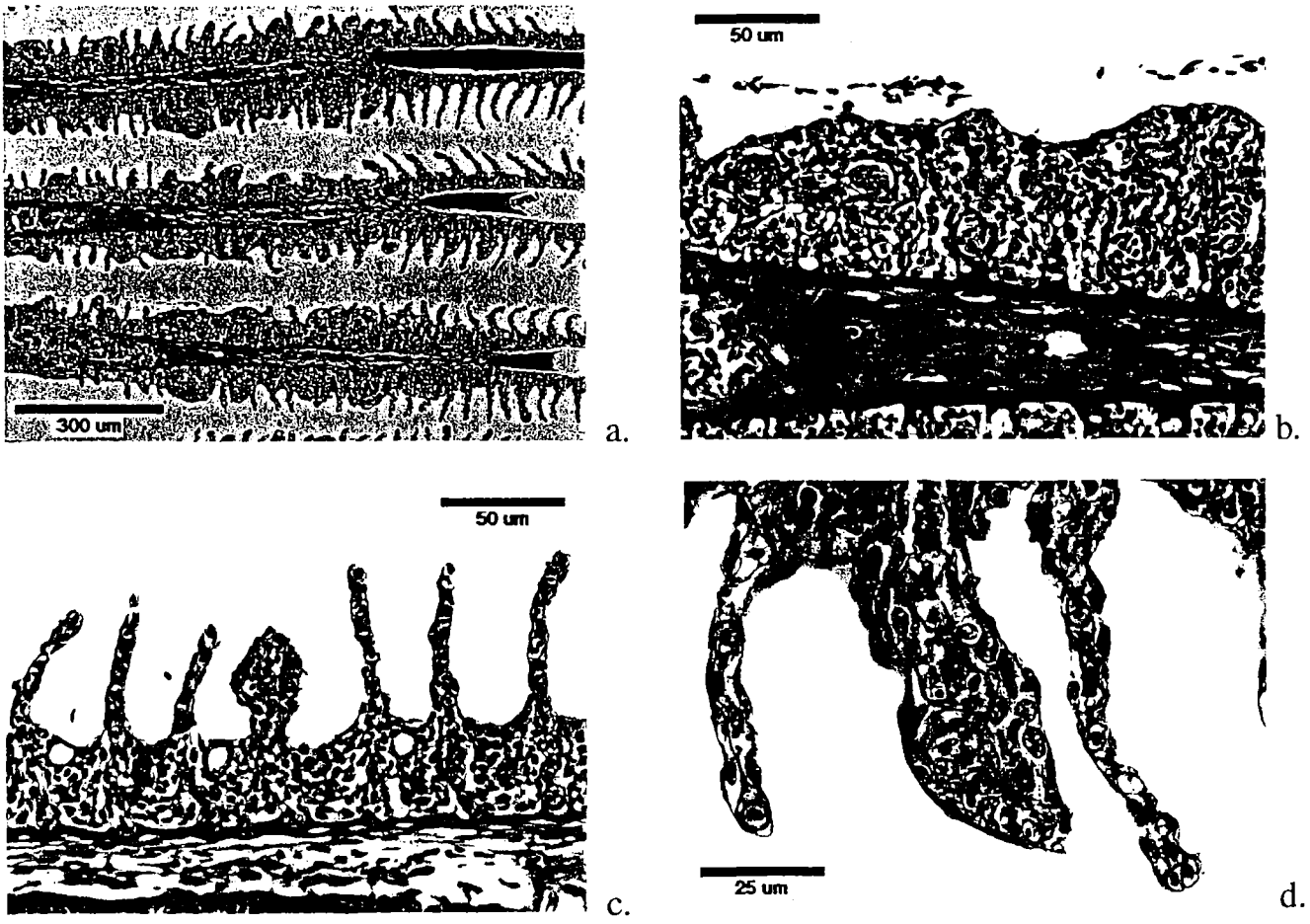

Plate 7. Pathological alterations in gills of mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Interlamellar hyperplasia. b) Higher magnification of figure a. c) Distal lamellar hyperplasia. d) Lamellar hyperplasia, higher magnification.

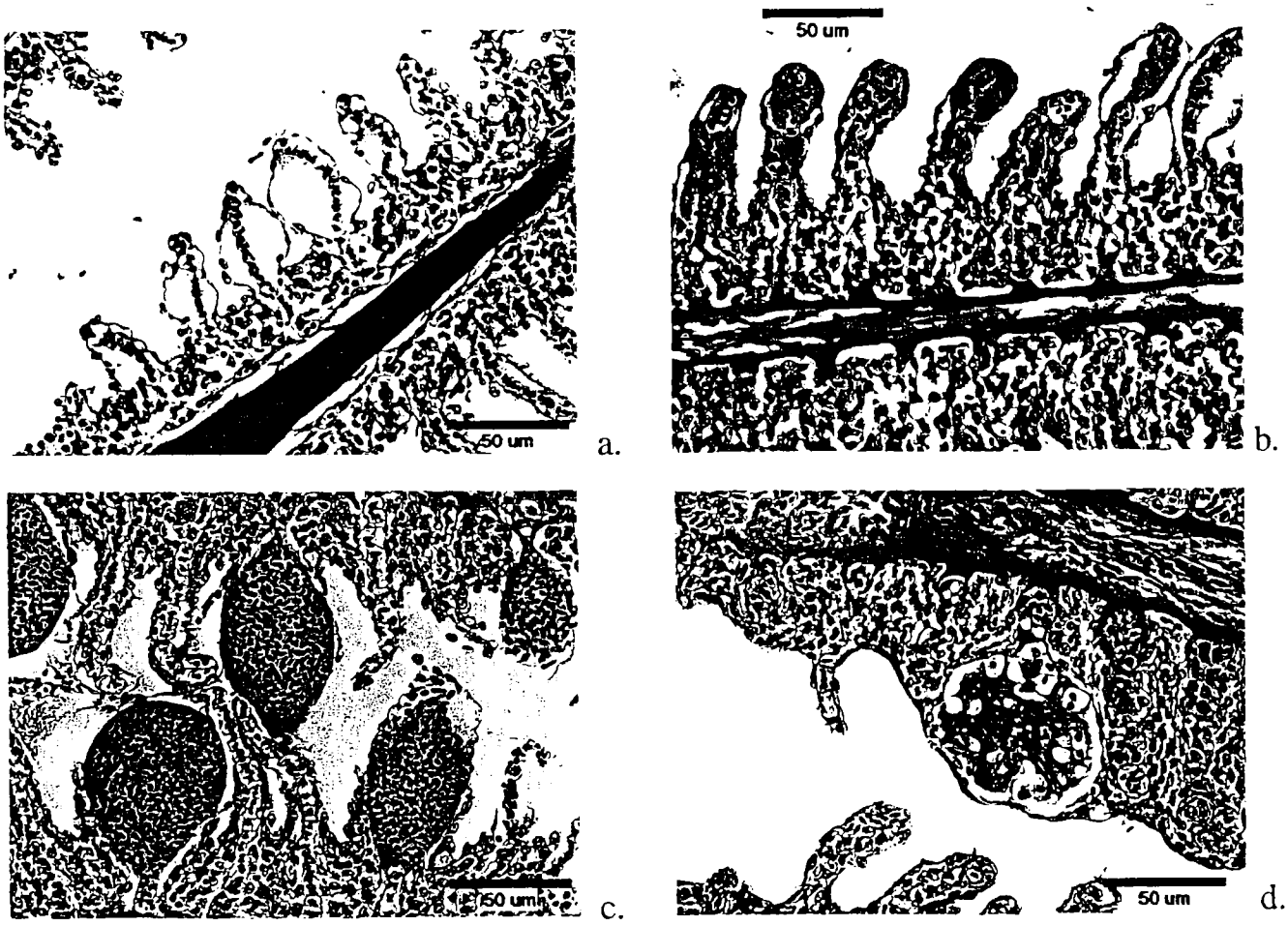

Plate 8. Pathological alterations in gills of mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Lamellar epithelial detachment with mild edema. b) Deposition of eosinophilic material in secondary lamellae. c) Lamellar telangiectasia. d) Lamellar thrombosis.

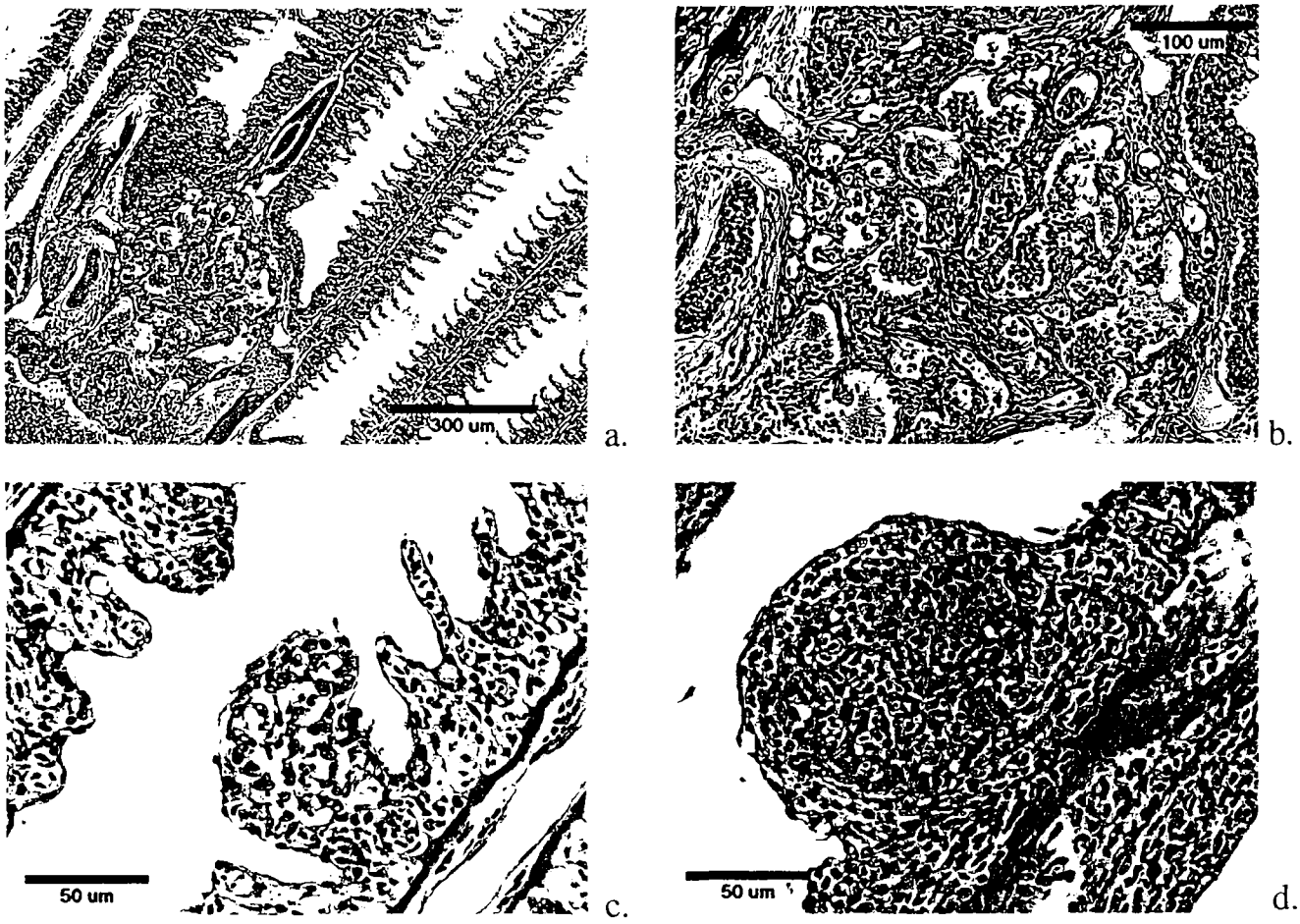

Plate 9. Pathological alterations in gills of mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Vascular proliferative lesion at base of primary gill filament. b) Higher magnification of figure a. c) Vasular proliferation response in distal tip of lamella. d) Vascular proliferation along primary gill filament.

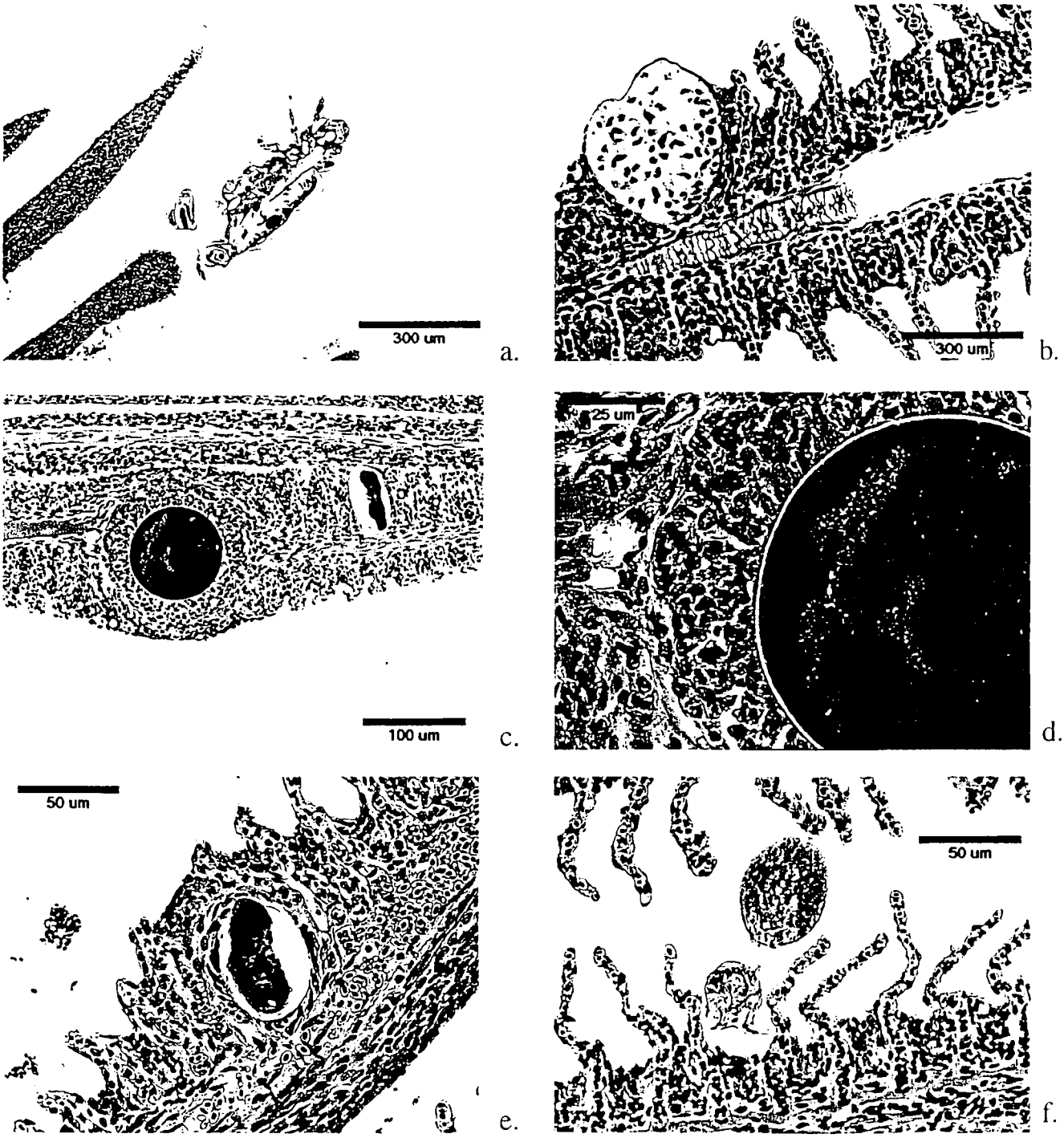

Plate 10. Infectious disease agents in gill tissue of mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Parasitic copepod attached to distal tip of primary gill filament. b) Myxosporidan infection of gill filament. c) Epitheliocystis sp. Infection and metacercarial stage of a digenetic trematode infecting gill filament. d) Higher magnification of figue c showing host cellular response to the parasite. e) Metacercaria of a digenetic trematode encysted in gill filament. f) Monogenetic trematode attaching to gill filament surface.

rapid high mortalities.

Gill Lesion Epizootiology

Prevalence data for seven selected pathological alterations of gill tissues in Elizabeth River mummichog are summarized in Figures 11 & 12. Few clear trend are evident in these data, however there is a trend of decreasing prevalences for lamellar hyperplasia (LH) and interlamellar hyperplasia (ILH) from the most industrialized sites to those that are more residential and removed from known sources of chemical input (Fig. 11). Prevalences of infectious disease agents in gill tissues are summarized in Figure 13. No clear trends related to industrialization are evident in these data.

Kidney Histology and Epizootiology

Kidney tissues have never been routinely evaluated by us in a pollution monitoring context. We therefore briefly illustrate and describe normal mummichog kidney structure (Plate 6a, b) and the common pathological alterations that we encountered in this study. Histologically kidney tissues in the mummichog consist in part of nephric elements responsible for ionic balance and blood filtration. Histologically the nephron consists of a vascularized filtration structure called the glomerulus which is located within Bowman's capsule lined by a parietal epithelium (Plate 6b). Histologically, various profiles of renal tubules and collecting ducts can be seen as well (Plate 6b). In contrast to mammals, the kidney of fishes is the predominant hemopoietic organ, with the interstitium (tissues between renal elements) occupied by hemopoietic tissues (various stages of developing and maturing rbc's and white blood cells) (Plate 8b). Blood sinuses filled with blood are common histological features of kidney as well (Plate 6a).

Pathological alterations of the Kidney

Pathological alterations of the kidney in Elizabeth River mummichog were mild in this study. Most of the lesions described here were uncommon and exhibited little relationship with industrialization and potential exposure to chemical contaminants. Mesangiosclerosis, an uncommon condition in Elizabeth River mummichogs, is illustrated in Plate 6c. This condition represents a deposition of eosinophilic fibrinous material within the glomerular tuft. Thickening and increased cellularity of the parietal epithelium of Boman's capsule is illustrated in Plate 6 d. Enlargement of Bowman's space, another uncommon condition, is figured in Plate 6 e. Ceroid pigments accumulate in many tissues of fishes and this pathological pigment was observed in mummichog kidneys as well. Plate 6 f illustrates a small ceroid granule in a glomerulus. Plate 7a illustrates a macrophage aggregate (immediately above the scale bar) replete with brown ceroid. Plate 7b figures deposition of ceroid within the renal tubular epithelium. Plate 7c illustrates accumulation of cellular debris within the lumen of a large collecting duct. Plate 7d illustrates a degenerating renal tubule the lume of which contains macrophages replete with ceroid. A large focus of macrophages replete with ceroid surrounds this degenerating renal tubule. Plate 7e

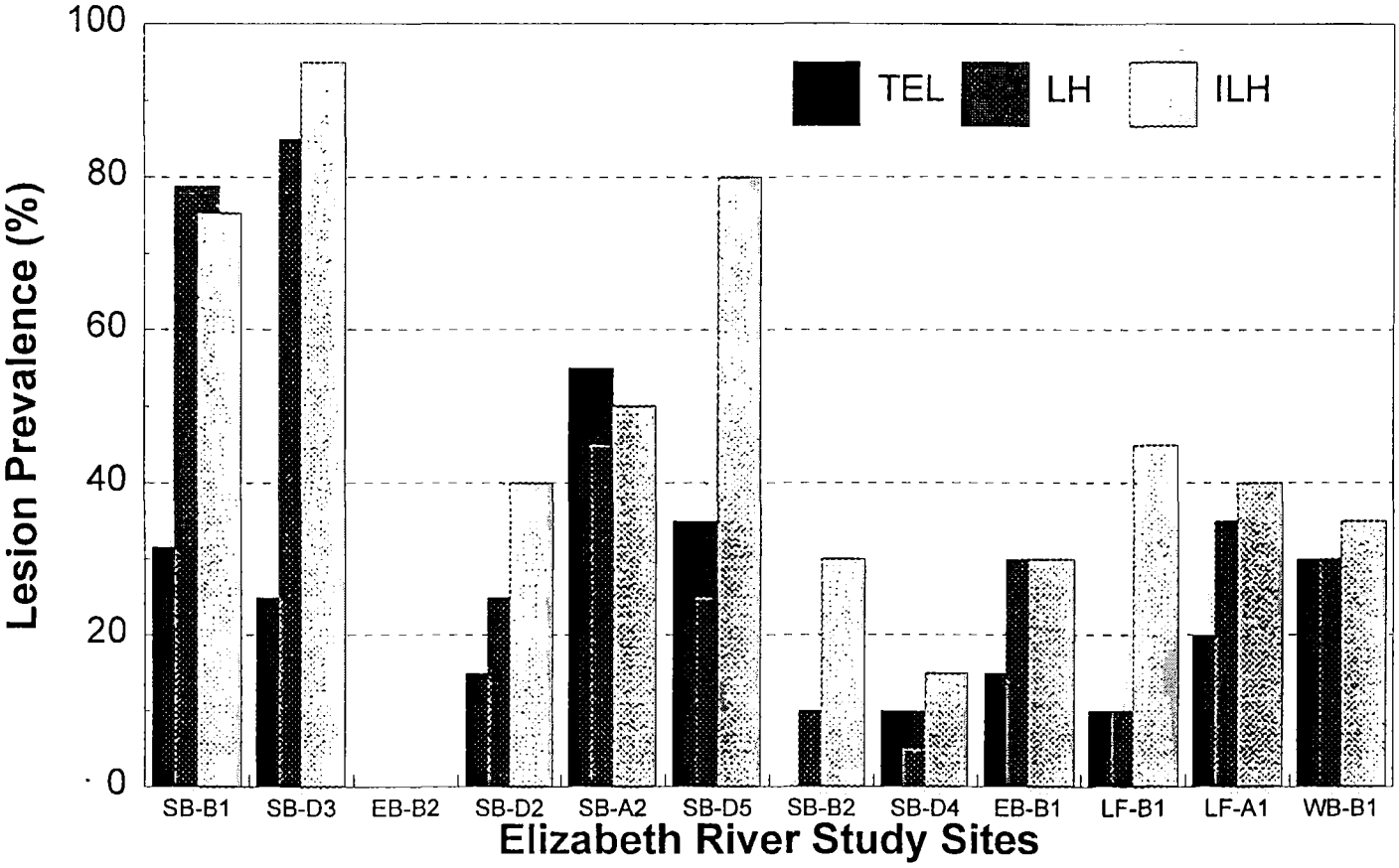

Figure 12. Gill lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. TEL: telangiectasis, LH: lamellar hyperplasia, ILH:interlamellar hyperplasia.

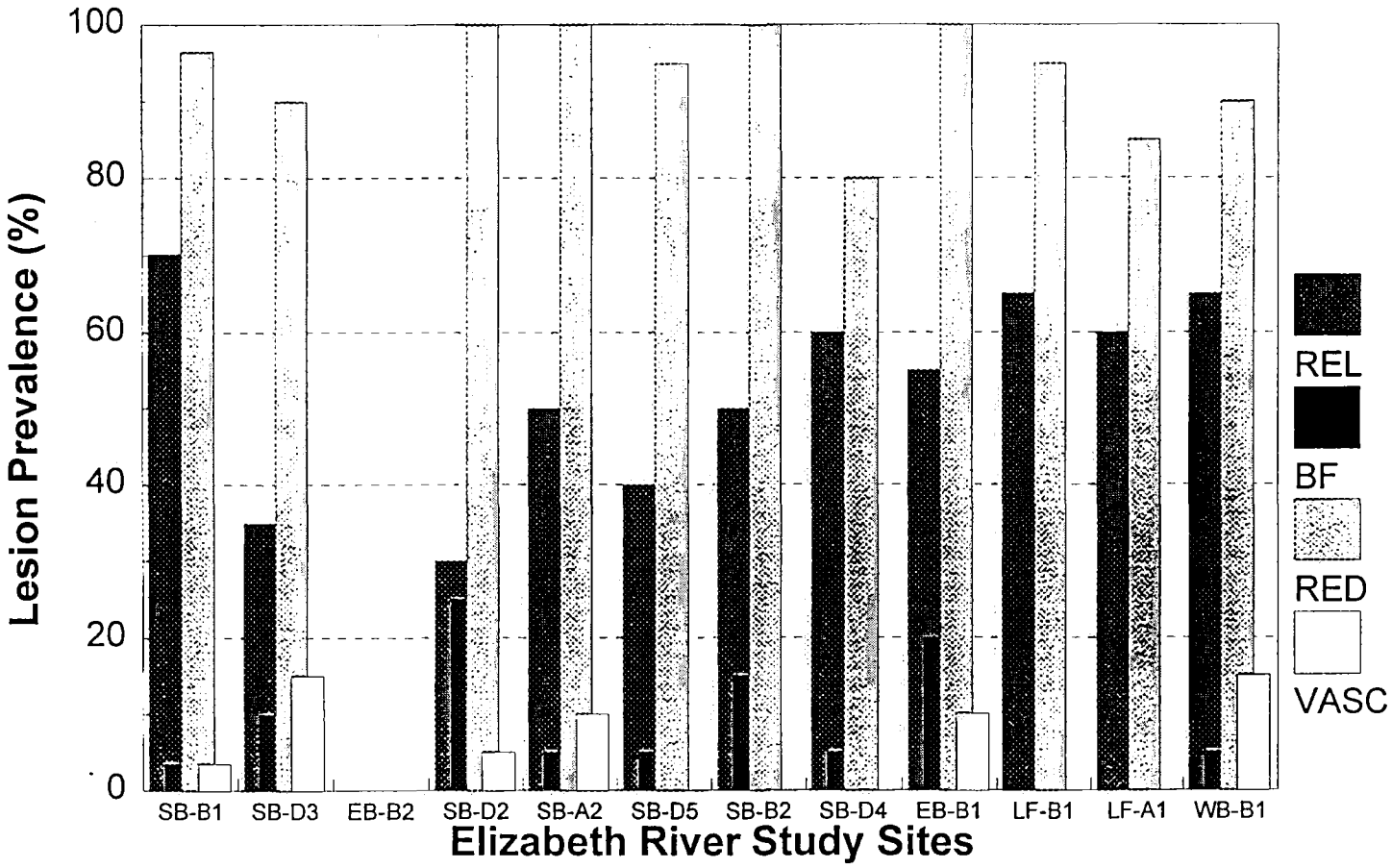

Figure 13. Gill lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River. REL: respiratory epithelial lifting, BF: branched gill filament, RED respiratory epithelial degeneration, VASC: vascular proliferation.

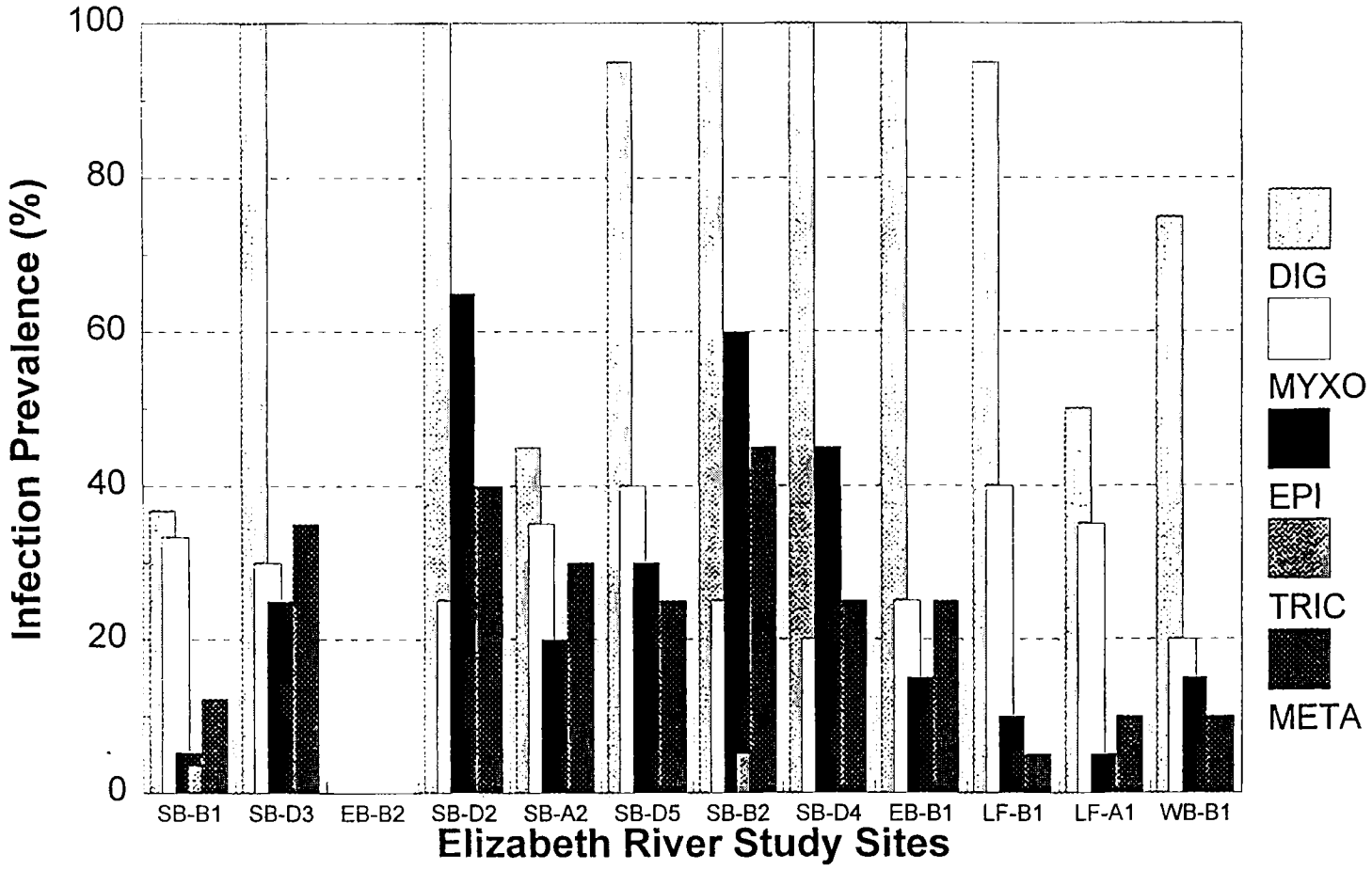

Figure 14. Infectious disease agents in gill of mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. DIG: metacercaria of digenetic trematode, MYXO: myxosporidan infection, EPI: Epitheliocystis sp., TRIC: Trichodina sp., META: unencysted metazoan parasite.

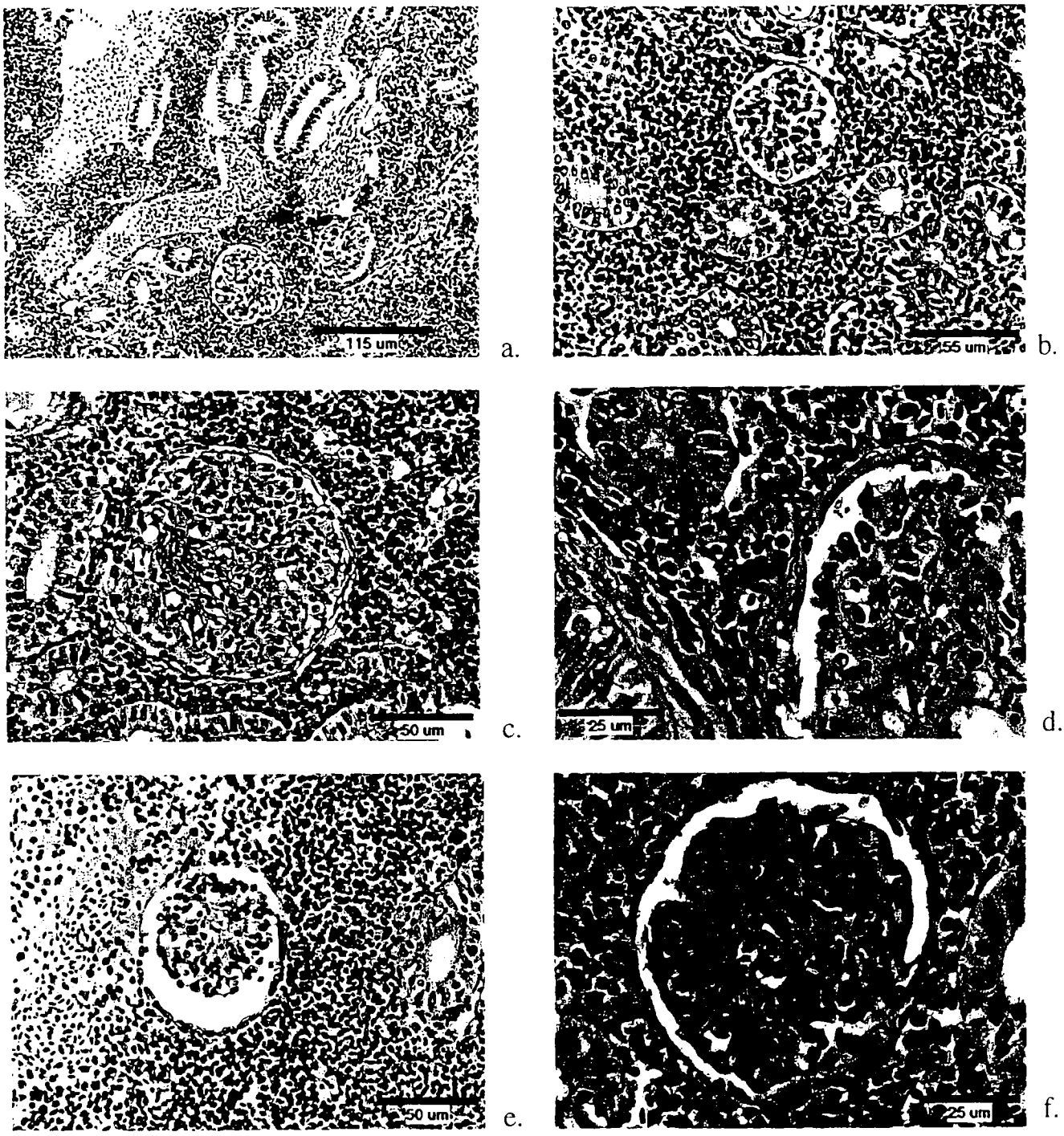

Plate 11. Normal histologic architecture and pathological alterations of the kidney in mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Low magnification overview showing renal elements, blood sinuses and interstitial hemopoietic tissues. b) Higher magnification showing a glomerulus, several renal tubules and interstitial tissues. c) Mild mesangiosclerosis. d) Thickening and increased cellularity of the parietal epithelium in Bowman's capsule. e) Enlarged Bowman's space. f) Ceroid accumulation within glomerular tuft.

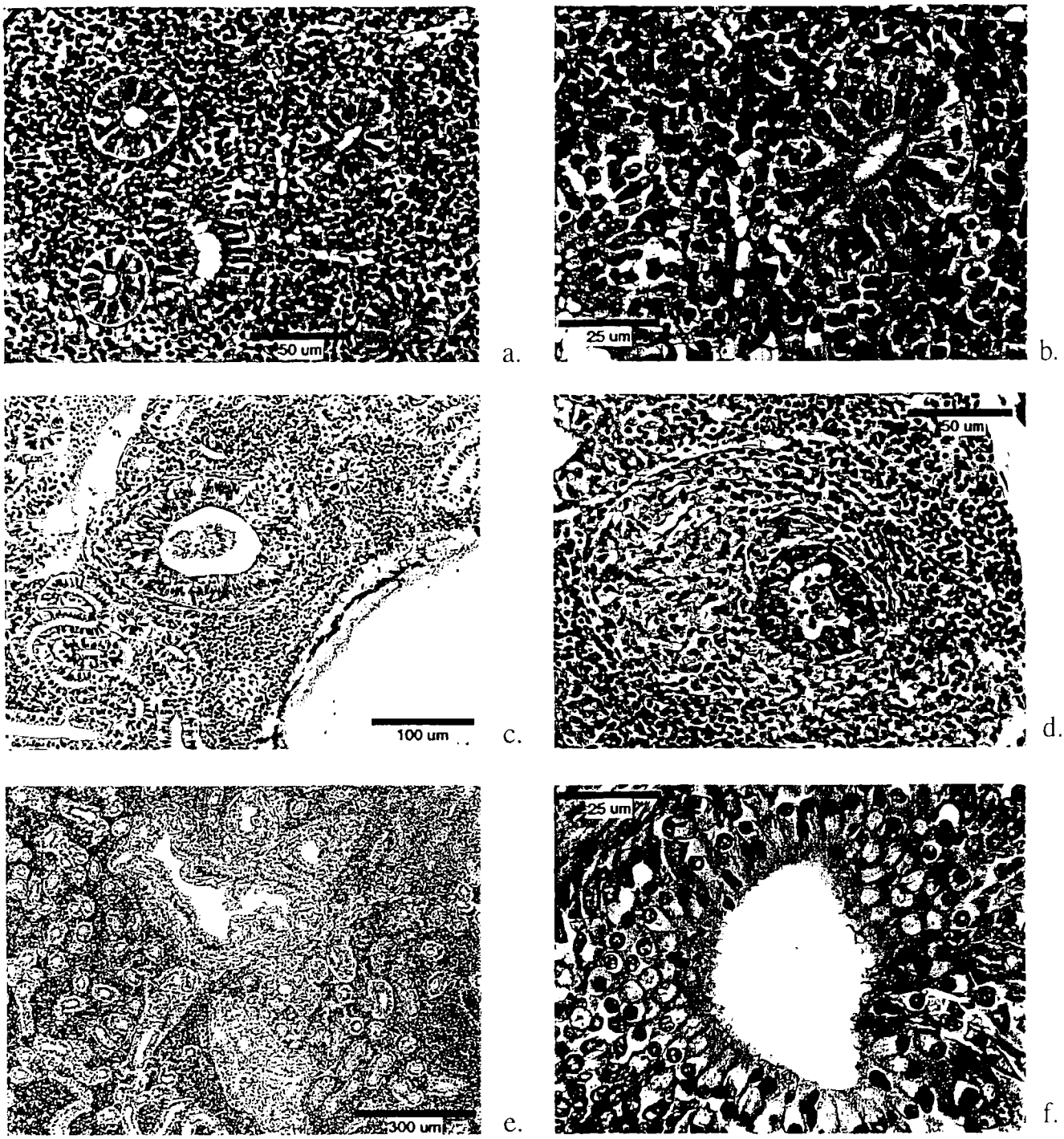

Plate 12. Pathological alterations of the kidney in mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Pigment containing macrophage aggregate in interstitial tissue. b) Ceroid accumulation within renal tubular epithelium. c) Cellular debris in collecting duct lumen. d) Degenerating renal tubule with associated inflammation. e) Duct cell proliferation. f) Higher magnification of figure 7e showing abundant Rodlet cells.

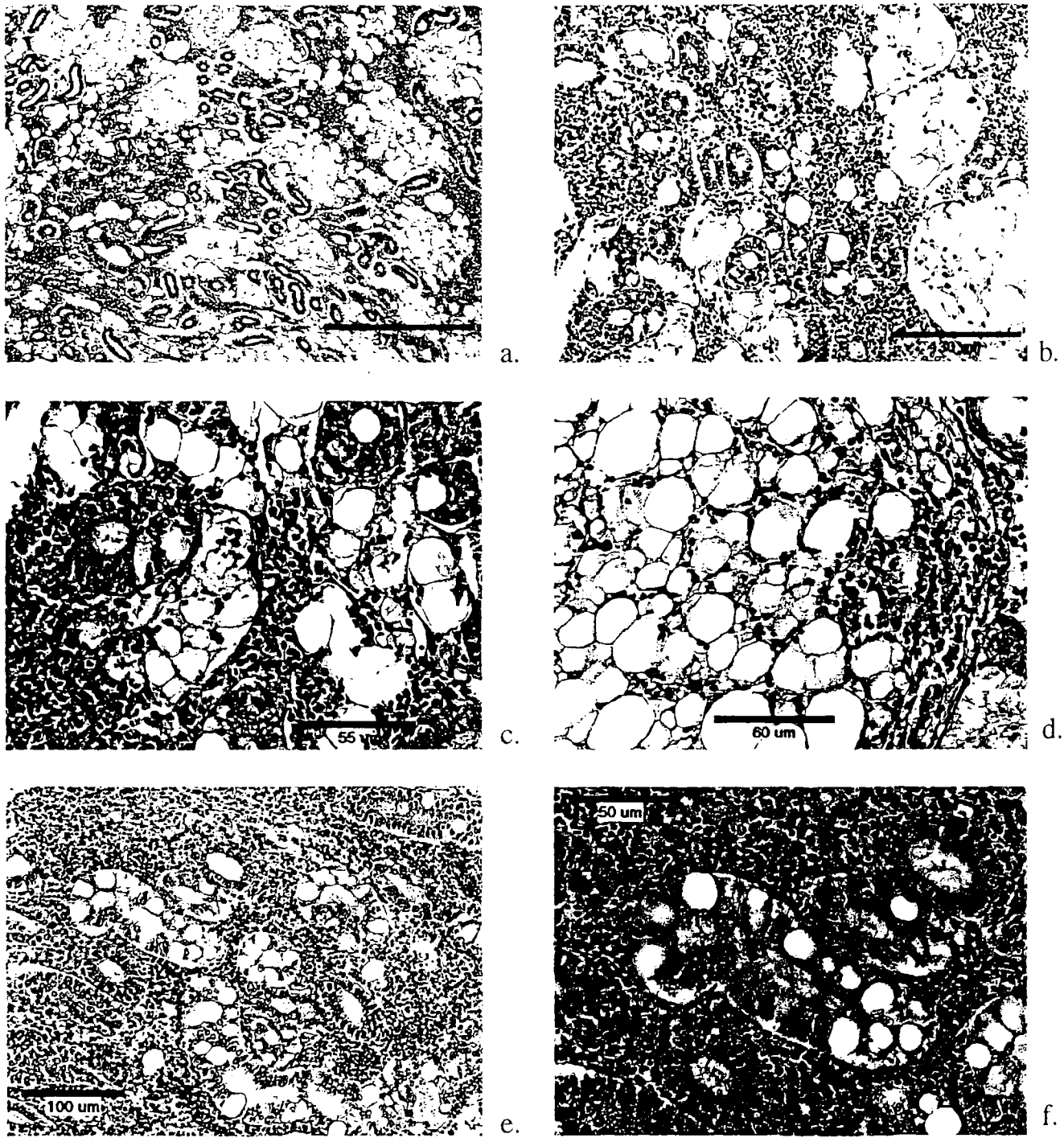

Plate 13. Pathological alterations of the kidney in mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Severe multi-focal vacuolation of renal interstitial tissues. b) Higher magnification showing lipid vacuoles and inflammatory response. c) Higher magnification of figure 8b. d) Fatty degeneration of interstitial tissue. e) Vacuolation of renal tubular epithelial cells. f) higher magnification of figure 8e.

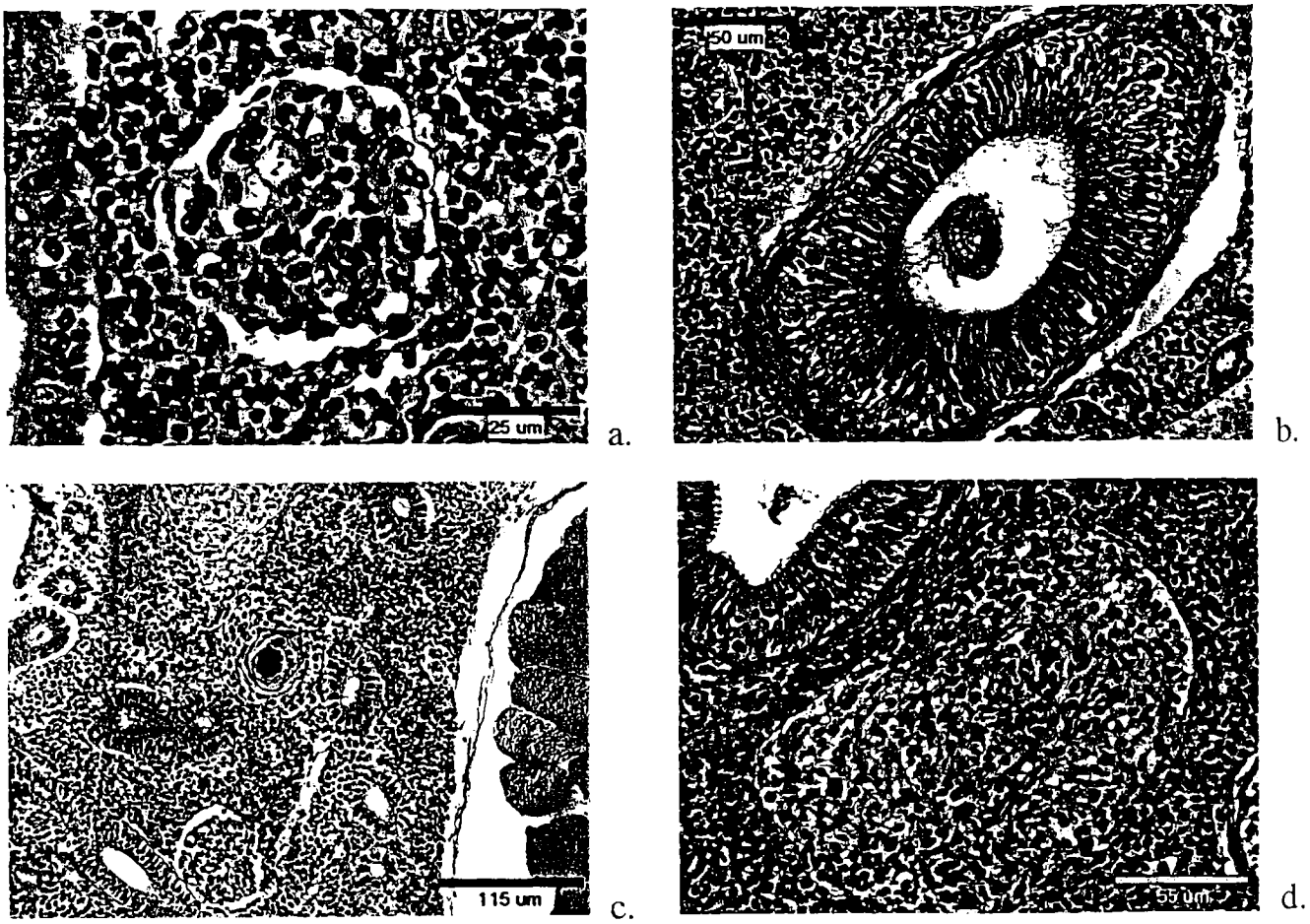

Plate 14. Pathological alterations of the kidney in mummichog, *Fundulus heteroclitus*, from the Elizabeth River, VA. a) Myxosporidan infection localized in glomerulus. b) *Trichodina* sp. In lumen of collecting duct. c) Granulomatous inflammation in interstitial tissues. d) Granuloma of undetermined etiology.

shows atypical proliferation of renal tubular epithelium. Plate 7f is a high magnification view of duct cell proliferation showing the presence of abundant rodlet cells. Plate 8a illustrates a severe multi-focalvacuolation response of the renal interstitial tissues. Plates 8b, c and d show this interesting condition at higher magnification. Note the presence of inflammatory leukocytes within these vacuolated foci (Plate 8c) suggesting that this is a degenerative condition. Plates 8e & f illustrate severe vacuolation of the renal tubular epithelium.

Infectious Disease Agents in Kidney

Infectious diseases were uncommon in the kidney tissues of Elizabeth River mummichog. Plate 9 a-d illustrate the rare infectious disease agents observed in this study. Plate 8aillustrates a mild myxosporidan infection of the glomerulus. Plate 8b illustrates a Trichodina sp. Infection in a collecting duct. Plates c & d illustrate typical granulomatous inflammatory lesions although an etiologic agent cannot be identified in these rooutinely stained sections.

Kidney Lesion Prevalence Data: Prevalence data for kidney lesions in mummichogs from the Elizabeth River are summarized in Figures 14 & 15. Few of the kidney lesions exhibit any trends with respect to industrialization. Cellular debris in renal tubular lumens (CDT) and macrophage aggregates (MA) exhibit minor trends with higher prevalences observed at the more industrialized and presumably more heavily impacted sites and lower prevalences at the more distant sites.

Kidney Infectious Disease Prevalence: Infectious disease prevalences are summarized in Figure 16. No trends are apparent in these data.

Parasite Diversity

Parasite diversity for mumichog from the 12 study sites is summarized in Figure 17. No trends are apparent in these data and no relationship with industrialization can be discerned.

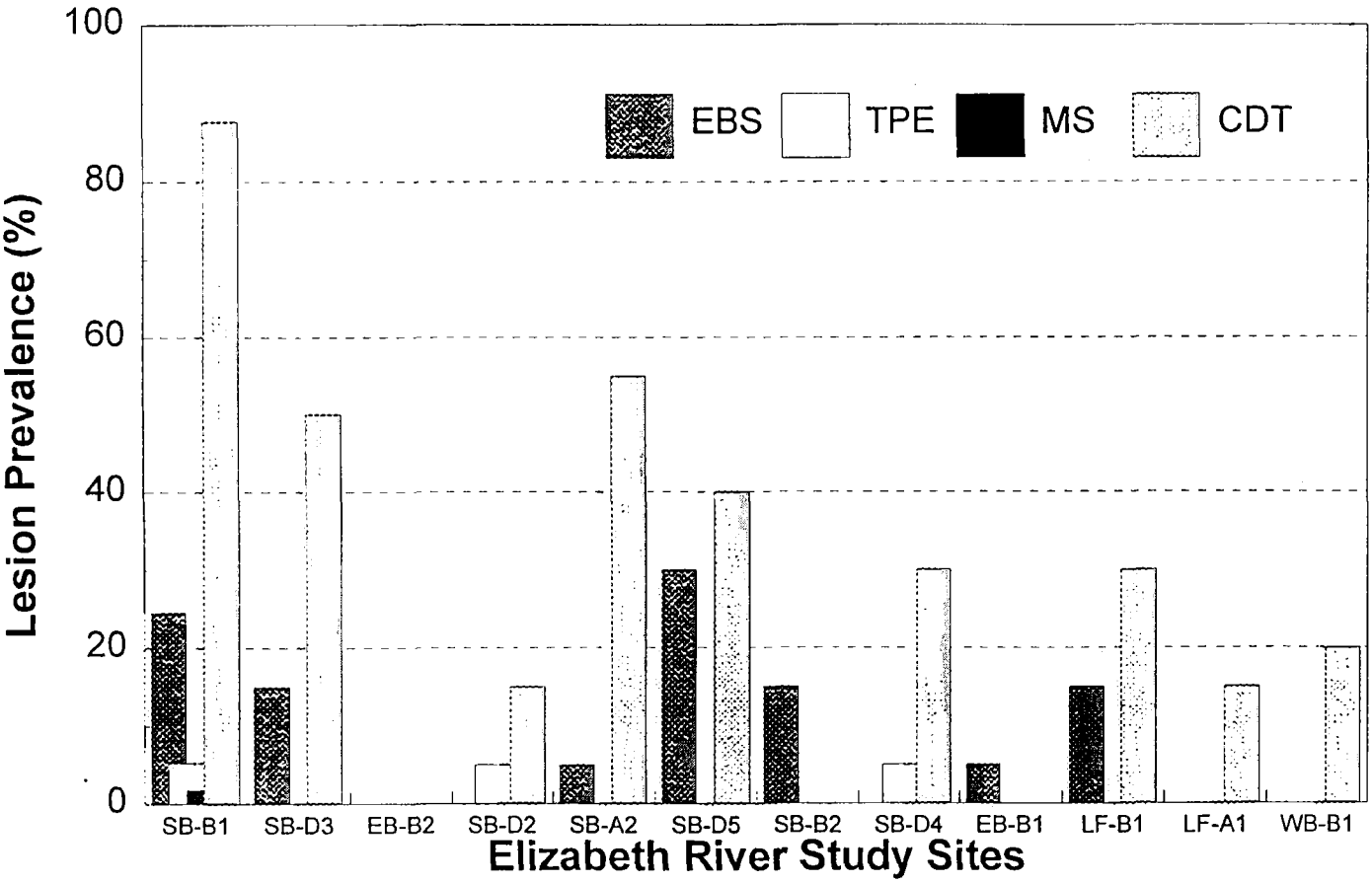

Figure 15. Kidney lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. EBS: Enlarged Bowman's Space, TPE: Thickened parietal epithelium, MS: Mesangiosclerosis, CTD: Cellular debris in tubule lumens.

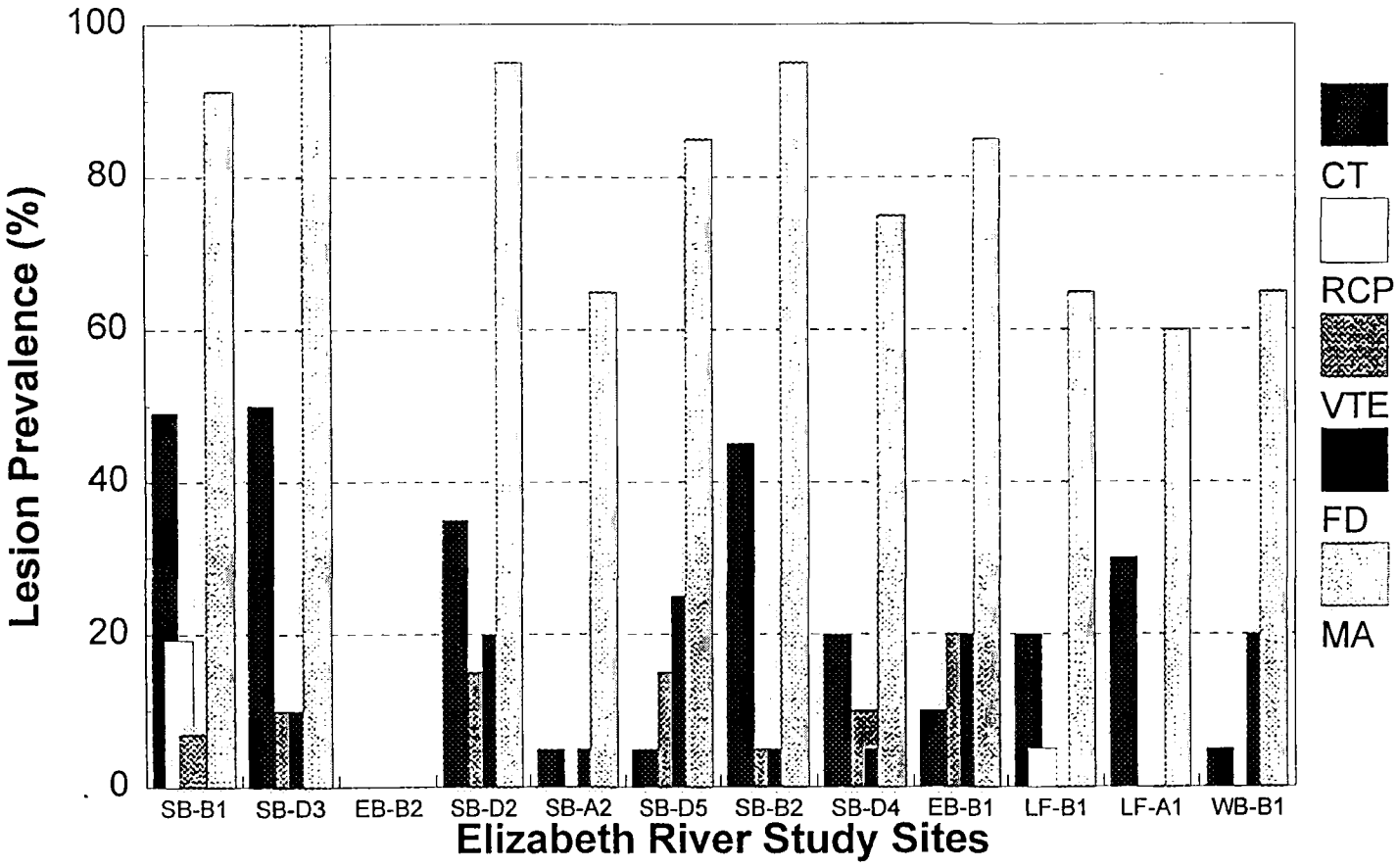

Figure 16. Kidney lesions in mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. CT: Ceroid in tubule epithelium, RCP: Rodlet cell proliferation, VTE: Vacuolation of tubular epithelium, FD: Fatty degeneration, MA: Macrophage aggregates.

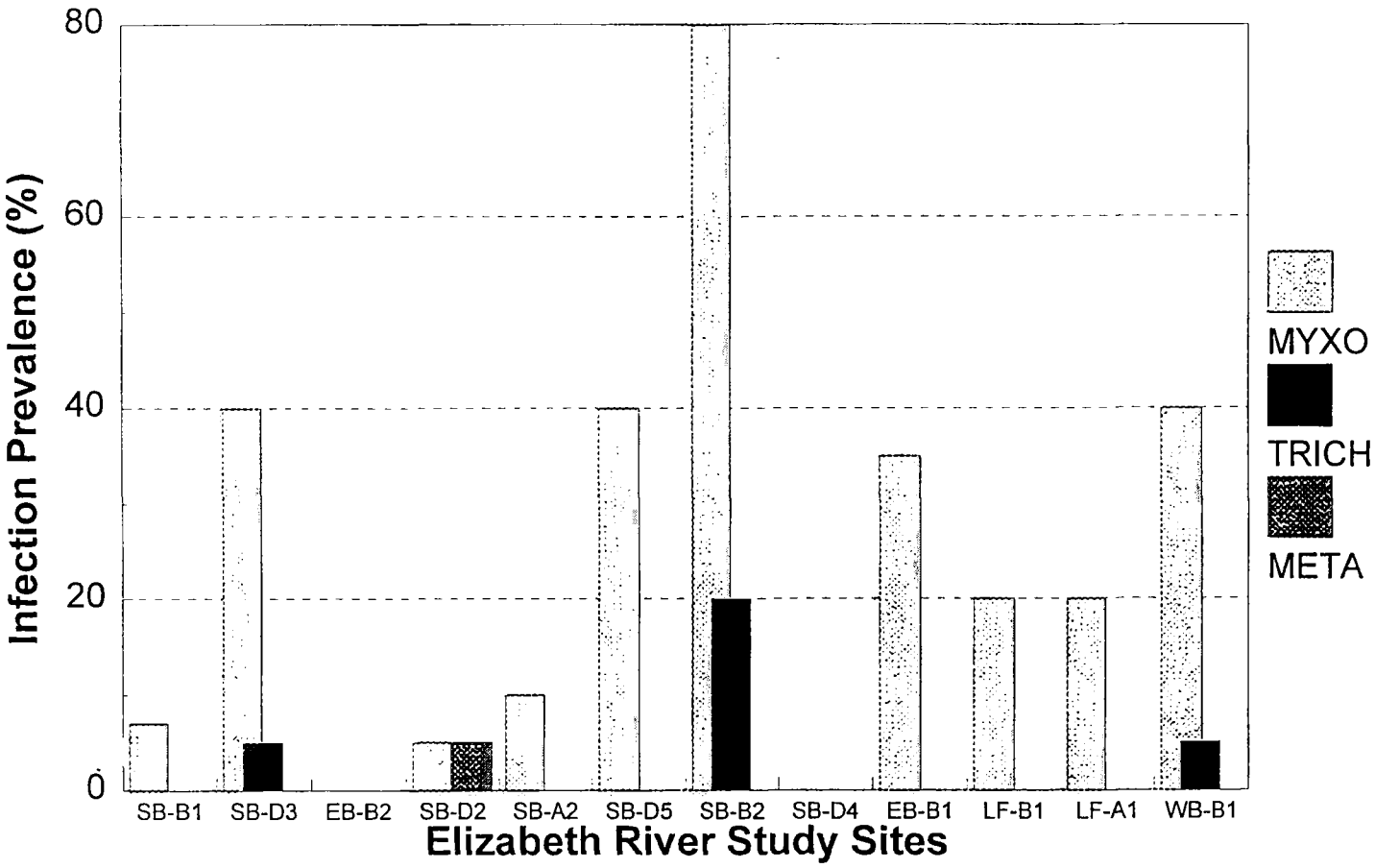

Figure 17. Infectious disease agents in kidney of mummichogs collected Nov 1998 from 12 study sites in the Elizabeth River, Virginia. MYXO: Myxosporidan infection, TRICH: Trichodina sp. infection, META: Encysted metazoan parasite.

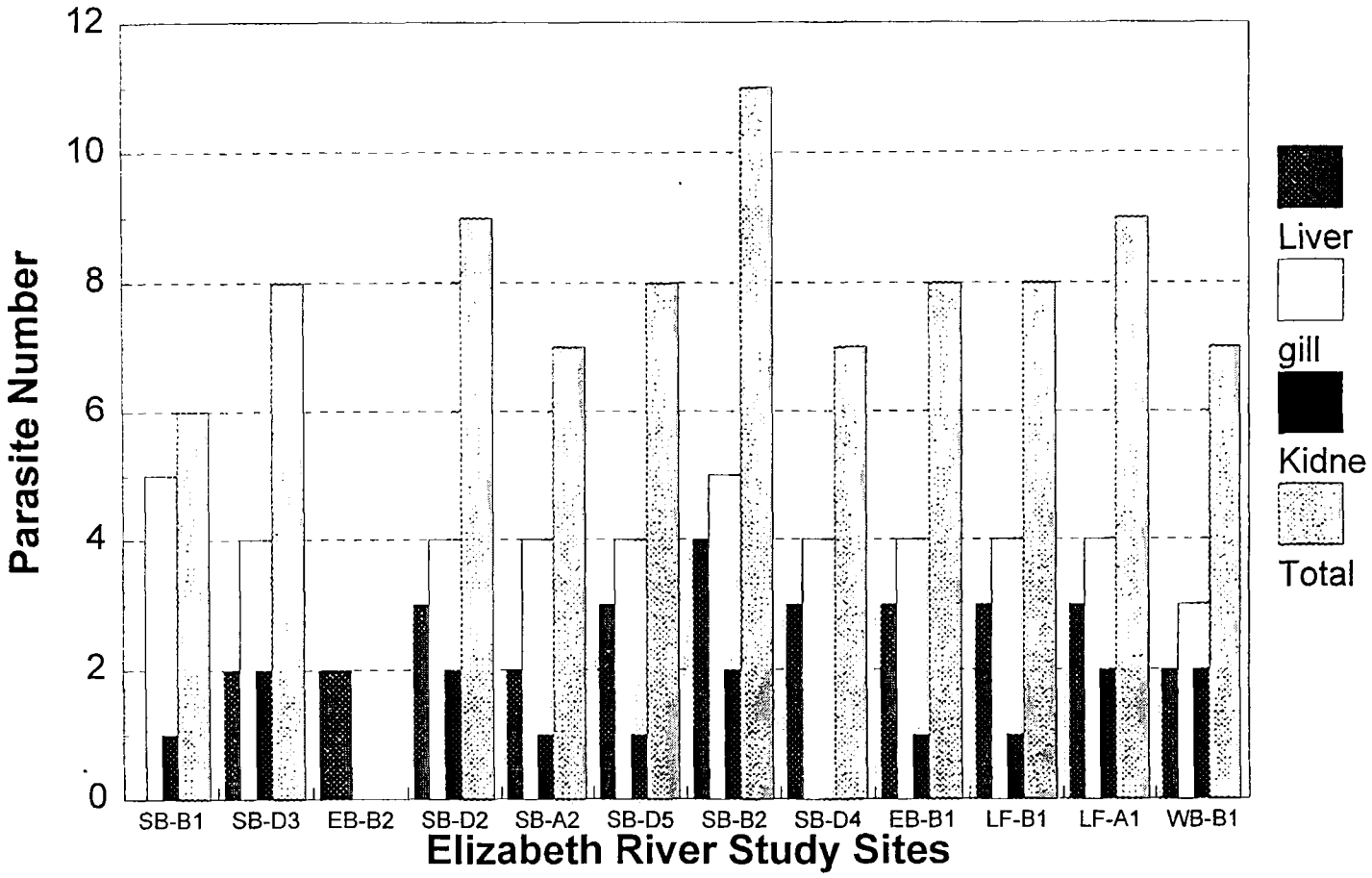

Figure 18. Parasite diversity in mummichog collected Nov 1998 from 12 Elizabeth River study sites.

Summary and Recommendations

The present study suggests that histopathological endpoints, especially those in the liver, are effective bioindicators of contaminant effects in Elizabeth River mummichogs, and that they can be used to characterize environmental quality. This is possible because the mummichog is largely non-migratory, with local sub-populations acting as effective integrators of bioavailable chemical contaminants. These fish thereby reflect the quality or "health" of the immediate environment in the types and severity of toxicant-induced pathologies present. Comparisons with other data sets from the present Elizabeth River Monitoring Program, such as chemical contaminant data and sediment toxicity tests have not yet been made. Therefore our conclusion is based largely on our own prior studies of this species and on what we know about the distribution of certain classes of chemical contaminants in the Elizabeth River.

This study represents an expansion of a preliminary evaluation of mummichog liver histopathology conducted during the spring of 1998. In that study we identified a broad range of liver lesion prevalences in fish from eight study sites. We also observed clear trends between the degree of industrialization at our study sites and the prevalence of hepatic proliferative lesions. In the present study we examined fish from 12 stations and evaluated two additional organs, the gill and the head kidney. We observed similar trends in the liver lesion data in this study and with the additional study sites have been able to expand our understanding of the spatial distribution of mummichog liver pathology within this heavily contaminated system.

In the present study, clear differences in lesion prevalences were observed for the hepatic proliferative lesions, some of the hepatotoxic lesions, and a few of the gill and kidney lesions. Strongest most significant trends were apparent in the proliferative liver lesions which we consider to be indicative of exposure to chemical carcinogens present in localized environments. Our recent laboratory exposure studies with creosote contaminated sediments and PAH amended sediment and diet provide strong support to the view that this class of lesions arises specifically in the mummichog from environmental exposure to PAHs. In contrast, the gill and kidney lesions observed in this study are all characterized as nonspecific changes. This means that they can be caused by a variety of different types of insult including toxicant exposure, poor water quality (e.g. elevated ammonia and nitrite), parasitic infection, and physical trauma. Because of this it is difficult to ascribe a specific chemical etiology to these lesions and to use them with any confidence in a pollution monitoring context.

Based on our fairly detailed understanding of the hepatic proliferative lesions in the mummichog, we can use prevalence and severity of these alterations to rank the quality of the 12 study sites evaluated in this investigation. Criteria for ranking study site quality based on the occurrence of hepatic proliferative lesions are outlined in Table 2. Based on these criteria, rankings for the 12 sites investigated in this study are as follows:

SB-B1.....4	SB-A2.....3	EB-B1.....1
SB-D3.....4	SB-D5.....2	LF-B1.....1
EB-B2.....3	SB-B2.....2	LF-A1.....1
SB-D2.....3	SB-D4.....2	WB-B1.....1

RANK	DEFINITION	EXPLANATION
0	**Insufficient/Inadequate data**	**No fish or too few fish (< 60) examined**
1	**Not a problem**	**Background liver lesion prevalences (Pre-cancerous AHF[1] < 5%, neoplasms[2] 0%).** Most reference sites (uninhabited and uncontaminated by apparent local sources) examined in our other studies of mummichog pathology exhibit AHF prevalence of 1-2%.
2	**Borderline**	**AHF 5-20%, neoplasms 0%**
3	**A problem**	**AHF at moderate prevalence (20-30%) neoplasms at low prevalences (< 5%)**
4	**A severe problem**	**AHF at high prevalence (> 30%) Neoplasms at high prevalence (>5%)**

[1]AHF: Altered Hepatocellular foci are small precancerous liver lesions
[2]Neoplasm: larger cancerous liver lesion that may be benign (adenoma) or malignant (carcinoma)

Table 2. Proliferative liver lesion based criteria for ranking the quality of selected Elizabeth River habitats.

Future monitoring efforts should focus on liver pathology because a number of these lesions can be attributed directly to toxicant exposure and therefore can serve as indicators of local environmental quality. The hepatic proliferative lesions in mummichog are perhaps the most specific, being indicative of carcinogen (e.g. PAH) exposure. Although some of the hepatotoxic lesions appear to exhibit a clear association with degree of industrialization and apparent toxicant inputs, they require further characterization and quantification. A future goal of ours is to develop computer based methods for quantitation of liver cytotoxic lesion severity with the aim of using these kinds of non-cancerous alterations to characterize the more moderately and mildly contaminated sites where we would not expect to see liver neoplasms. Development of quantitative methods would allow us to use these liver lesions in a pollution

monitoring context. Our evaluation of the gills and kidney indicate that pathological alterations in these organs, even in the most heavily contaminated study sites, are minor and largely non-specific. Although we have been able to show some minor trends that suggest an association between contaminant inputs and lesion prevalence in these organs, it is unlikely that any of these non-specific lesions can ever be linked directly to chemical exposure of natural fish populations. We therefore suggest that evaluations of these organs be dropped in the future. This would allow available resources to be used for more promising monitoring endpoints and would make the histopathological evaluations more cost-effective and streamlined.

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ATTACHMENT C

PHASE I SEDIMENT INVESTIGATIONS

FINAL

Data Report
Elizabeth River Environmental Restoration
Feasibility Investigation
Phase I Sediment Investigation
Elizabeth River, Virginia

Prepared for

Department of the Army
U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, VA 23510-1096

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August 1999

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ABBREVIATIONS, ACRONYMS, AND UNITS

AET	Apparent Effects Threshold
CAB	Cellulose Acetate Butyrate
CBP	Chesapeake Bay Foundation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chain-of-Custody
DEQ	Department of Environmental Quality
DGPS	Differential Global Positioning System
DQO	Data Quality Objectives
DVR	Data Validation Reports
EA	EA Engineering, Science, and Technology, Inc.
EDS	Environmental Data Services, Inc.
ERL	Effects Range Low
ERL-N	Environmental Research Lab-Narrangansett
ERM	Effect Range Median
ERP	Elizabeth River Project
FCSA	Feasibility Cost Sharing Agreement
FD	Field Duplicate
FSP	Field Sampling Plan
ft	foot
ft^3	cubic feet
HNO_3	Nitric Acid
LCS	Laboratory Control Sample
MB	Method Blank
mg/kg	milligram per kilogram (ppm)
mg/L	milligram per liter (ppm)
MDL	Method Detection Limits
MLLW	Mean Lower Low Water
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAD	North American Datum

PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PCT	Polychlorinated Terphenyl
PEL	Probable Effects Limit
PP	Priority Pollutant
ppm	parts per million
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limits
SDG	Sample Delivery Group
SQG	Sediment Quality Guidelines
SSHP	Site Safety and Health Plan
SVOC	Semivolatile Organic Compounds
TEL	Threshold Effects Limit
TOC	Total Organic Carbon
ug/kg	microgram per kilogram (ppb)
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1. PROJECT DESCRIPTION

1.1 PROJECT BACKGROUND

The Elizabeth River in Norfolk, Virginia has been identified as a "Region of Concern" in the Chesapeake Bay watershed. The Chesapeake Bay Program (CBP) has given this designation to only three areas of the Chesapeake Bay (the Elizabeth River, the Anacostia River, and Baltimore Harbor). Sediment contamination in each "Region of Concern" is higher than that found anywhere else in the Bay. Concentrations of several contaminants in each of these regions exceed the Effect Range-Median (ER-M) benchmark values (Long *et al.* 1995), posing a significant risk to the health of aquatic organisms (Alden and Winfield 1995). These "Regions of Concern" have, therefore, been targeted for investigation and remediation.

The Norfolk District U.S. Army Corps of Engineers (USACE); the Commonwealth of Virginia; and the cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach have entered into a Feasibility Cost Sharing Agreement (FCSA) to implement a Feasibility Study to evaluate environmental restoration of wetlands and sediment within the Elizabeth River Basin. The day-to-day management of the Feasibility Study is conducted by a Steering Committee, comprised of representatives from Federal and Non-Federal sponsors of the project and representatives from local resource agencies, academic institutions, and interest groups. The Steering Committee reviews field study design and progress, prepares and evaluates work documents, and coordinates public involvement in the project.

The long-term objective of the Elizabeth River, Virginia Environmental Restoration Project is the implementation of wetland restoration and sediment remediation to improve the quality of the aquatic habitat and shoreline.

The sediment remediation component of the project consists of three phases (USACE 1998a):

- Phase I: characterization of each site to identify potential contaminants of concern.
- Phase II: comprehensive evaluation of lateral and vertical extent of contamination at Scuffletown Creek and toxicity testing of sediments from Scuffletown Creek, Scotts Creek, and East of Campostella Bridge.
- Phase III: identification of potential treatment technologies for identified contaminants of concern.

The Norfolk District USACE is responsible for implementing the Phase I sediment investigation.

1.2 PROJECT PURPOSE

The Phase I Sediment Investigation represents one component of the large-scale remediation and restoration initiative for the Elizabeth River Basin. EA Engineering, Science, and Technology, Inc. conducted the Phase I sediment investigation for the Norfolk District USACE during the period of February though June 1999. Four specific areas of the Elizabeth River, selected by the Steering Committee, were investigated in the project: Scuffletown Creek, Scotts Creek, east of the Campostella Bridge, and adjacent to the prior Eppinger and Russell site.

The sampling and analysis of the sediment was required to:

- Document existing physical and chemical characteristics of the sediment in each of the four sites;
- Identify potential chemicals of concern; and
- Identify areas that may require further investigation.

This Data Report presents a synopsis of the Phase I sampling program and the results of bulk chemistry testing for each of the four project areas in the Elizabeth River. The project schedule, list of key personnel, Field Sampling Plan (FSP), laboratory Quality Assurance Project Plan (QAPP), and Site Safety and Health Plan (SSHP) are documented in the Work Plan (EA 1999) that was submitted to and approved by Norfolk District USACE and the members of the Steering Committee in March 1999.

1.3 PROJECT OBJECTIVES

The short-term objectives of the Elizabeth River Phase I sediment investigation were to:

- Collect sediments representative of each the four proposed remediation areas of the Elizabeth River (Scuffletown Creek, Scotts Creek, East of Campostella Bridge, and prior Eppinger and Russell site).
- Test bulk sediments for semivolatile organic compounds, organochlorine pesticides, polychlorinated biphenyl (PCB) aroclors and congeners, polychlorinated terphenyl (PCT) aroclors, priority pollutant (PP) metals, total organic carbon (TOC), and physical characteristics (grain size).
- Provide validated, analytical data in a usable format.
- Compare validated, analytical data to selected Data Quality Objectives (DQOs) (marine sediment quality guidelines).

The chemical data generated by the Phase I sediment investigation will be used by the Steering Committee to:

- Describe the physical and chemical condition of the existing bottom substrate;
- Identify potential contaminants of concern;
- Evaluate the need for additional studies; and
- Develop recommendations for Phase II sediment investigations.

1.4 DESCRIPTION OF THE PROJECT AREA

The Elizabeth River is located approximately 135 miles southeast of Washington, D.C. at the junction of Hampton Roads, Virginia and the Chesapeake Bay. The river is a tidal estuary that flows through the cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach and into the James River near the mouth of the Chesapeake Bay (Figure 1-1). The watershed encompasses approximately 300 square miles and approximately 145 square miles are tidally influenced (USACE 1998b). Four area of the Elizabeth River were investigated in the Phase I project: Scuffletown Creek, Scotts Creek, east of the Campostella Bridge, and adjacent to the prior Eppinger and Russell site (Figure 1-1).

1.4.1 Scuffletown Creek

Scuffletown Creek is a tributary to the Southern Branch of the Elizabeth River. The creek is located on the east bank approximately two nautical miles from the Eastern Branch/Southern Branch confluence in the city of Chesapeake. The proposed remediation/restoration site is bordered by Bainbridge Boulevard at the head of the creek in Chesapeake, and by the eastern edge of the Federal navigation channel at the mouth of the creek. Water depths range from 1ft to10 ft MLLW (mean lower low water). A large derelict vessel is located near the mouth of the creek and numerous pilings are situated in the headwaters near the south shore (VMRC 1997).

On the west of the creek bank, less than 0.5 miles across the river, there are two former creosote plants that were operated in the 1920s, Atlantic Wood Industries and Wycoff Pipe and Creosote (USACE 1997a). Atlantic Wood is a Superfund Site that is currently under remedial action. Wycoff Pipe and Creosote is adjacent to property owned by Portsmouth Port and Industrial Commission. At this site, there is a high probability of PAH contamination in the sediments from the former creosote facilities. Previous studies in the vicinity of the Atlantic Wood site revealed pentachlorophenol (PCP), PAHs, heavy metals, and dioxins/furans (King 1995). In addition to contamination from the creosote facilities, there may be contaminants from leachate and stormwater runoff from a dumping area east of the Elizabeth River Park (USACE 1997a). There are also ship repair facilities on the southern side of the mouth of the creek.

1.4.2 Scotts Creek

Scotts Creek is located in the City of Portsmouth and flows into the mainstem of the Elizabeth River from the west bank. The proposed remediation/restoration area consists of the entire creek with branches extending to Booker Street, London Boulevard, Leckie Street, and Harrell Street in Portsmouth. Water depths range from 0.5 ft to 9 ft MLLW. At least six derelict vessels are located within Scotts Creek (VMRC 1997).

Three major stormwater outfalls, draining more than 800 acres of industrial, commercial, and residential land empty into the south branch of Scotts Creek at London Boulevard (USACE 1997a). Little data exist regarding the health or characteristics of the bottom sediments in Scotts Creek. It is anticipated that contamination originates from extensive stormwater runoff in the south branch of the creek (USACE 1997a).

1.4.3 East of Campostella Bridge

The site east of the Campostella Bridge is located approximately 1-3/4 nautical miles east of the Eastern Branch/Southern Branch confluence. The site is located in a small cove east of the Campostella Bridge and adjacent to the Campostella Heights neighborhood in the city of Norfolk. The proposed remediation/restoration area is bordered at the west by the east side of the Campostella Bridge and at the east by the western edge of the mouth of Steamboat Creek. Water depths range from 1 ft to 16 ft MLLW. Based on the Elizabeth River Derelict Vessel Inventory (VMRC 1997) and reconnaissance investigations, three derelict vessels are located in the cove area east of the bridge. In addition, there is a temporary barge mooring area located approximately 100-ft east of the bridge, a sunken barge approximately 150-ft east of the bridge, and a buried high voltage cable crossing in the vicinity of the bridge.

Ship repair facilities are located across the river (Norfolk Shipbuilding and Drydock) and upriver (Colonna Shipyard) from the site (USACE 1997a). Sediment contamination at this site likely originates from historical ship building and repair activities. In addition, there is an existing construction fill site located near the Campostella Heights neighborhood.

1.4.4 Eppinger and Russell

The Eppinger and Russell site is located on the Southern Branch, 3 1/2 nautical miles south of the Southern Branch/Eastern Branch confluence, in the city of Chesapeake. The remediation/restoration area is located offshore of the Amerada Hess property, directly past Freeman Avenue. The site is bounded on the west by the eastern edge of the Federal navigation channel. Water depths range from 3 ft to 28 ft MLLW. The area is referred to as "Money Point" by local residents.

The Eppinger and Russell site may be the most heavily PAH-contaminated region in the Elizabeth River (USACE 1997b). The area has a long history of wood treatment activities dating as far back as the turn of the century. In 1900, the Norfolk Wood Treatment Plant began operations at the site. Around World War II, Eppinger and Russell purchased the plant and

continued operations until 1980. The facility treated 500,000 to 1,200,000 ft^3 of wood per year, with 1946-47 being the peak processing years. Wastewater containing creosote was directly discharged into the river before the Korean War (1950-1953). In 1963, a fire at the Eppinger and Russell plant resulted in a creosote spill into the river. In 1967, ruptured tanks spilled 20,000 to 30,000 gallons of creosote into the river (Mu Zhen Lu 1982). Following the 1967 spill, the Lone Star Company, during river dredging operations, encountered a nearly pure pool of creosote on the river bottom approximately 0.25-miles downstream of the spill location.

1.5 HISTORY OF CONTAMINANTS AND PREVIOUS INVESTIGATIONS

Both industrialization and urban development have impacted the health of the Elizabeth River's ecosystem. Previous studies of the Elizabeth River indicate that stormwater runoff, point source discharges, and spills from commercial, industrial, and military sources have impacted water and sediment quality of the area. Historically, creosote plants, shipyards and drydocks, oil terminals and various coal-loading facilities that lined the river's banks contributed to both organic and inorganic contamination. In addition, the system has suffered from a severe and rapid loss of wetland and vegetated buffer areas along its 350-mile shoreline. The majority of wetland and vegetation loss is attributed to a combination of dredging, filling, and urban/industrial development.

High concentrations of organic and inorganic chemical pollutants have adversely impacted aquatic life in the Elizabeth River. Health problems in finfish, such as fin rot, skin lesions, tumors, cataracts, and other physiological and morphological abnormalities, have been documented in the river (USACE 1997a). Aquatic toxicity tests have indicated that bottom sediments from creosote-contaminated areas are highly toxic to resident fish species (Roberts *et al.* 1989). Benthic studies in the Southern Branch of the Elizabeth River classify the benthic communities as highly stressed (Dauer 1993 and 1994). In addition, bioaccumulation of contaminants and mutagenic chemicals in blue crab tissue poses a threat to human health (Alden and Winfield 1993).

Heavy metals and polynuclear aromatic hydrocarbons (PAHs) are the primary contaminants of concern in the river. Shipyard activities and urban stormwater runoff are potential sources of heavy metal contamination, and petroleum products, coal, incomplete combustion of fossil fuels, creosote, and urban stormwater are potential source for elevated PAH concentrations (Alden 1995 cited by USACE 1997a). In addition to heavy metals and PAHs, pentachlorophenol, tributyl tin, phthalates (plasticides), PCBs (polychlorinated biphenyls) and other priority pollutants have been reported in the river (Canonizado *et al.*, 1996). PAHs are known carcinogens, and phthalates (used in solvents) are potentially toxic irritants. Tributyl tins are associated with antifouling agents used in shipbuilding.

Dredging has removed some of the contaminated sediments in the system, but only within the channel areas. The shoreline, shallow water areas adjacent to the shoreline, and other areas outside the maintained navigation channels serve as a sink for contaminants. The nearshore

areas in the vicinity of existing or historical industrial and shipyard facilities have a high potential for elevated levels of pollutants.

Previous investigations of the Elizabeth River have documented regional sediment quality (USEPA 1976; Aldin *et al.* 1991; King 1995), water quality (Aldin *et al.* 1988), impacts to aquatic biota (Aldin and Blandin 1994), loss of wetlands (Priest and Hopkins 1997) and potential remediation alternatives (Canonizado *et al.*1996). No previous investigations, however, have characterized the site-specific physical and chemical quality of sediments in the proposed remediation and restoration areas identified by the Steering Committee.

1.6 REPORT ORGANIZATION

This Data Report contains a comprehensive summary of field activities and results of bulk sediment testing for the Elizabeth River Phase I Sediment Investigation. The field sampling program for the project is described in Chapter 2. Chapter 3 presents the analytical testing protocols, data validation procedures, and DQOs utilized in the investigation. Tabular summaries of chemical and physical data for each site are presented in Chapter 4. Project-specific observations and recommendations are provided in Chapter 5. A list of cited references is provided in Chapter 6.

Copies of field log notebooks and electronic data logs are provided in Appendix A (Volume II). Data validation protocols are provided in Appendix B (Volume II). Detailed results of the grain size analyses are provided as Appendix C (Volumes III and IV). Data validation reports, including chain-of-custody documentation, case narratives, and Form Is, are provided as Appendix D (Volumes V through VIII).

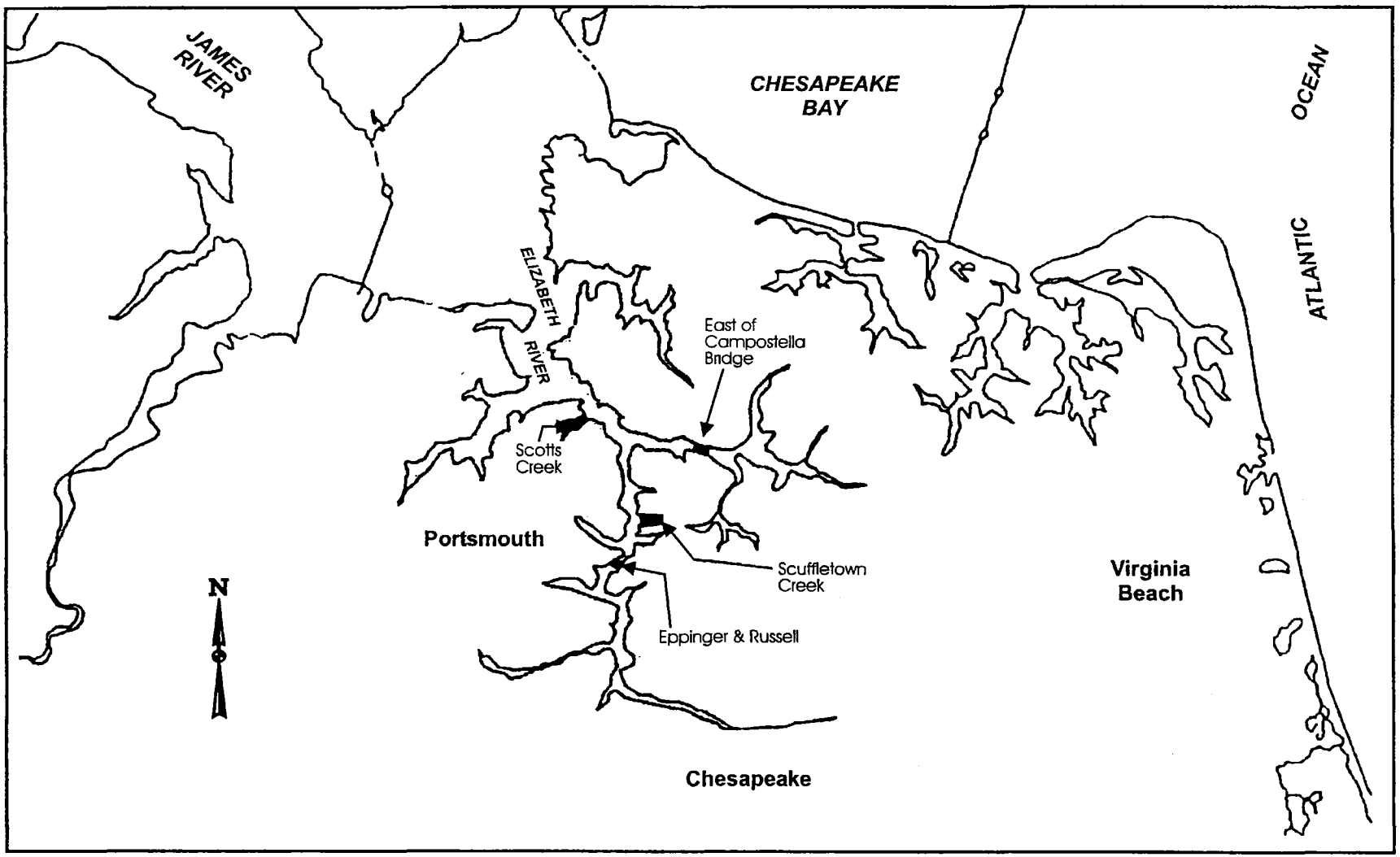

Figure 1-1. Study Area Locations for the Elizabeth River Phase I Sediment Investigation.

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2. FIELD INVESTIGATION PROCEDURES

2.1 OVERVIEW OF FIELD SAMPLING ACTIVITIES

Mobilization for the Elizabeth River Phase I Sediment Investigation commenced in February 1999. Sample collection was initiated on 03 March 1999 and continued through 27 April 1999. Sampling activities began at the previous Eppinger and Russell site, and proceeded to the Scuffletown Creek area, followed by East of Campostella Bridge and Scotts Creek. A total of 244 stations were successfully sampled out of 281 target locations. Sampling was attempted at every targeted location, with the exception of those stations that were located onshore. The majority of sediment cores were collected using gravity coring techniques, however, hand coring was required at 23 locations where access was difficult due to either low bridges or shallow water depth.

A total of 689 cores were collected and composited for chemical analysis. In addition, 29 cores were collected from the prior Eppinger and Russell site for photography and lithological description. The number of cores collected at each station was dependent upon the sediment recovery in each core. Stations in Scuffletown Creek and at the prior Eppinger and Russell site required the collection of at least two cores to obtain the sample volume required for analytical testing and QC analysis. Only a few stations in Scotts Creek and East of Campostella Bridge required collection of more than one core. A detailed summary of coring activities is provided in Appendix A.

Overall, only 36 of the 281 targeted stations were not successfully sampled (13%). Insufficient sample recovery precluded successful sediment collection at 7 target locations (5 in Scuffletown Creek and 2 East of Campostella Bridge) (Table 2-1). In addition, 29 of the targeted stations were located onshore (28 at Scuffletown and one at Scotts Creek) (Table 2-1).

2.1.1 Scuffletown Creek

A total of 148 of 181 targeted locations were sampled in Scuffletown Creek. Actual sampling locations are depicted in Figures 2-1A, 2-1B, and 2-1C. Station coordinates are provided in Table 2-2. Sampling at 40 stations (22%) in Scuffletown Creek yielded insufficient sediment recovery from the 1-2 ft depth interval to conduct analytical testing (Figure 2-1D and Table 2-1). In addition, five stations located in Scuffletown Creek yielded either no sediment recovery or insufficient recovery to conduct analytical testing for both the 0-1 ft and 1-2 ft depth intervals (Figure 2-1E and Table 2-1). Twenty-eight locations at Scuffletown Creek were not sampled because the stations were located onshore (Figure 2-1F and Table 2-1). Hand coring was employed to sample 11 stations located east of and under the Interstate 464 bridge.

2.1.2 Scotts Creek

A total of 31 of 32 targeted locations were sampled in Scotts Creek. Actual sampling locations are depicted in Figures 2-2A and 2-2B. Station coordinates are provided in Table 2-3. One target station for Scotts Creek was located onshore (Figure 2-2C) and was not sampled. In

addition, hand coring was employed at 12 shallow locations in the southernmost areas of Scotts Creek.

2.1.3 East of Campostella Bridge

A total of 32 of 34 targeted locations were sampled East of Campostella Bridge. Actual sampling locations are depicted in Figures 2-3A and 2-3B. Station coordinates are listed in Table 2-4. Originally, target locations were located east of the Campostella Bridge. However, the fine grid was re-located by Norfolk District USACE to the west of the Campostella Bridge to sample an area of suspected contamination. After initial site reconnaissance and prior to sampling, stations located east of the Campostella Bridge were adjusted to avoid a barge mooring area located east of the bridge, a sunken barge, and an underground high voltage cable crossing the river parallel to the bridge. In the field, stations CBF004 and CBF008 were re-adjusted approximately 100 ft to the east due to a floating dry dock located over the target locations. Sampling at two stations located east of the bridge yielded either no sediment recovery or insufficient recovery to conduct analytical testing (Figure 2-3C and Table 2-1).

2.1.4 Eppinger and Russell

A total of 34 of 34 targeted locations were sampled near the prior Eppinger and Russell site. Actual sampling locations are depicted in Figures 2-4A and 2-4B. Station coordinates are provided in Table 2-5. Samples collected from 5 locations were submitted for analytical testing and 29 cores were photographed and described for lithology.

2.2 SAMPLING OBJECTIVES

The field investigation consisted of obtaining sediment cores from four proposed remediation areas in the Elizabeth River, processing and compositing the sediment, and submitting the sediment to EA Laboratories for physical and chemical analysis.

The objectives of the field sampling and sample processing efforts were:

Field Sampling

- Collect sediment cores at 281 stations in 4 defined areas to minimum depths of –2 ft below the sediment surface.
- Obtain the required volume necessary for analytical testing.
- Submit equipment and field blanks for analytical testing.
- Transport sediment cores to EA's facility in Sparks, Maryland under temperature-controlled conditions (4° C) and according to the requirements of chain-of-custody protocols.

- Complete appropriate chain-of-custody documentation.

- Photograph 29 sediment cores taken at the Eppinger and Russell site, visually inspect cores for evidence of contamination, and visually describe sediment types and distribution.

Sample Processing

- Extrude sediment from core liners.

- Composite and homogenize sediments according to protocols that ensure sample integrity.

- Submit processing blanks for analytical testing.

- Distribute homogenized sediment samples into appropriate containers for submittal to appropriate laboratories (either EA Laboratories or EPA Environmental Research Lab-Narragansett (ERL–N).

- Complete appropriate chain-of-custody documentation.

2.3 STATION LOCATION DETERMINATION

2.3.1 Target Locations

Prior to sampling, target station locations for the project were determined using a two-dimensional Systematic Grid Sampling Strategy at each site. This strategy entailed overlaying a "coarse" grid and a "fine" grid on each site. The "coarse" grid covered the entire site, except where a "fine" grid was used to focus on areas of known or suspected contamination. Grid specifications were provided by Norfolk District USACE and are displayed in Table 2-6. Information regarding areas of known or suspected contamination was also provided by Norfolk District USACE.

Stations in each of the four proposed remediation areas were located at least 50 ft offshore to avoid shallow areas and relic pilings and barges. Maps and coordinates of the proposed target locations are provided in the project Work Plan (EA 1999). Sampling grids for each proposed remediation area were approved by Norfolk District USACE prior to sampling.

2.3.2 Field Methodology

Positioning was determined in the field using a Trimble ProXRS Differential Global Positioning System (DGPS). The ProXRS uses the United States Coast Guard Differential Beacon System to obtain differential accuracy of 3-5 meters. The DGPS antenna was located directly over the lifting point where the gravity corer was lowered into the water for the reading of the core location.

Station locations were referenced to the Virginia State Plane Coordinate System North American Datum (NAD) 1983. Sample locations were modified in the field for some of the target stations to avoid obstacles (such as old pilings, dolphins, and docks) or debris. Copies of field logs and a core-by-core summary of sampling activities are provided in Appendix A. Actual sampling location coordinates, water depth, number of cores composited per station, and depth of sediment composited from each station are provided in Tables 2-2 through 2-5. Actual sampling coordinates were averaged and plotted for stations where two or cores were collected. Averaged locations are provided in Tables 2-2 through 2-5 and plotted on Figures 2-1A through 2-4B.

2.4 SAMPLE COLLECTION

2.4.1 Gravity Coring

Gravity coring was conducted from EA's 26-ft work boat equipped with a gantry and hydraulic winch for coring operations. The following procedure were used to collect sediment cores at each station with a gravity corer:

- A clean, decontaminated 3 ft section of cellulose acetate butyrate (CAB) plastic liner was fitted with a clean stainless steel core catcher at the bottom and a pressure-relief valve at the top.
- The liner was placed inside the gravity corer.
- A clean stainless steel core cutter, or nose cone, was being placed at the bottom of the gravity corer.
- The boat was maneuvered onto station location. If wind and/or current speeds were high the boat was anchored. Otherwise, the boat remained unanchored during coring operations.
- If water depth was greater than 5 ft, the corer was lifted over the rear of the boat, lowered until the top of the corer was just above the waterline and secured with a line. If water depths were less than 5 ft, the corer was secured to the top of the gantry and secured with line. The crew released enough wire off of the winch to allow free-fall of the corer into the sediment.
- When the corer was close to the target station location the line securing the corer was released, allowing the corer to free-fall and penetrate the sediment.
- The winch operator then wound-in the winch wire until it was taught, and the actual position of the corer was recorded from the DGPS unit.

- The approximate water depth was recorded from the depth sounder located inside the cabin of the boat.

- After position was recorded, the gravity corer was brought up on deck.

- The core liner was removed from the corer, the core catcher was removed from the bottom of the core, a core cap was placed on the bottom of the core, and the cap was taped in place. The core was then moved into a vertical position and excess liner above the sediment-water interface was cut off with a hacksaw and clean hacksaw blade. The top of the core was then capped and taped.

- The liner and both caps were labeled. Labeling included the following information:

  - Station Location/Site
  - Unique sample ID
  - Core No. of Total No. of Cores for Station
  - Reference to top or bottom

- The process was repeated at the site after the boat's position was moved 1-10 ft if additional sediment volume was required at the station.

- The boat was then relocated to the next station, and the process repeated.

2.4.2 Hand Coring

Workboat access to the area of Scuffletown Creek located east of the Interstate 464 bridge was impossible due to low height of the bridge and shallow water depths. In addition, access to the southern-most stations in Scotts Creek was also impossible with the large work boat due to shallow water depths. In order to obtain samples, EA personnel hand cored from a small jon boat in these areas. The station locations where hand coring was used to recover sediment are provided in Tables 2-2 and 2-3 for Scuffletown Creek and Scotts Creek, respectively. The same procedure for positioning with the gravity corer was followed for the hand coring, and clean, decontaminated core liners were used. After the jon boat was positioned on station, a liner was pushed into the sediment by hand to an approximate penetration depth of 2 ft. The core was then retrieved by placing a clean, decontaminated core cap at the top of the liner and pulling the liner out of the sediment. The top cap created a vacuum that held sediment in the liner during retrieval. Excess liner above the sediment/water interface was cut off with a hacksaw and clean hacksaw blade. The caps were taped and the caps and liners were labeled.

2.4.3 Core Storage

Cores collected during the work day were stored in cooled containers on board the boat. Cores were transferred to a refrigeration unit (cooled to 4°C) at the on-shore staging area at the end of each work day. After completion of coring activities at the end of the week, the sediment cores

were transported in an insulated container to EA Engineering in Sparks, Maryland. The cores were then stored in a secured refrigeration unit at EA (maintained at 4°C) until they were processed. A chain-of-custody form accompanied the cores during transport to Sparks, MD. The chain-of-custody form documented core name and date and time of collection.

2.4.4 Field Duplicates

To fulfill QA/QC requirements, duplicate cores were collected at 19 stations. Field duplicate cores were collected at 15 stations in Scuffletown Creek, 2 stations East of the Campostella Bridge, 1 station in Scotts Creek, and at 1 station at the prior Eppinger and Russell site. The duplicate cores were collected at locations approximate to the initial sampling locations, but were offset sufficiently to ensure that the same exact locations were not sampled. Field duplicate samples submitted for analysis from Scuffletown Creek were representative of the 0-1 ft depth interval. A list of the field duplicate samples is provided in Table 2-7.

2.5 SAMPLE PROCESSING

Cores were processed in a designated area at EA's warehouse facility. A logbook was maintained for the sample processing operation. Information relevant to sample processing (cores processed, dates, time, personnel names, and deviations from the work plan) was recorded in the logbook as samples were processed and submitted to the laboratories for analyses. Prior to processing, cores were sorted and checked against the chain-of-custody forms.

Sediments were extracted from each core using a stainless steel extrusion rod, composited, and homogenized in pre-cleaned, stainless steel bowls. For samples that required the analysis of 0-1 ft or 1-2 ft depth intervals (Scuffletown Creek), the cores were cut at the 1 ft and 2 ft interval using a hacksaw with a decontaminated hacksaw blade. Sediment for each depth interval was extracted and homogenized separately. Some samples, especially at Scuffletown Creek, required compositing of 2 or more cores. For the 1-to-2 ft interval, some cores did not have complete 1-to-2 ft sections, (i.e. one section was 2 ft and another section was less than 2 ft.) When this occurred, both cores were cut to even length (the length of the shortest core). The depth of the sediment for the composited sample was recorded. Each sample was homogenized until the sediment was thoroughly mixed and of uniform consistency. When compositing and homogenization were completed, sub-samples of sediment were removed for bulk chemistry testing and submitted to EA Laboratories.

Holding times for the sediment samples began when the sediment was removed from the core liner, composited, homogenized, and placed in the appropriate sample containers. Sample containers, preservation techniques, and holding requirements for sediment samples are provided in Table 2-8.

Sample containers containing the processed sediment were labeled with the following information:

- Client
- Project number
- Sample ID
- Station location
- Date and time of collection
- Sampler's initials
- Type of analysis

A chain-of-custody form was submitted to EA Laboratories when the processed sediment was hand delivered to the laboratory.

2.6 FIELD, EQUIPMENT, AND PROCESSING BLANKS

Holding times for the field, equipment, and processing blanks began when the sample was collected and placed into the appropriate sample containers. Sample containers, preservation techniques, and holding time requirements for blanks are provided in Table 2-9.

2.6.1 Field Blanks

A total of twenty-six field blanks were submitted to EA Laboratories for analysis. Field blanks consist of deionized water that was transported to the field site and accompanied the samples during the collection process. The deionized water was transferred directly to sample containers for analyses. Field blanks were analyzed for SVOCs, priority pollutant metals, and TOC. Five of the 26 field blanks were analyzed for organochlorine pesticides. Four field blanks were analyzed for PCB aroclors and congeners and PCT aroclors. Field blanks were sent to EA Laboratories via overnight delivery on the day of collection. Chain-of-custody documentation was submitted with the field blanks.

2.6.2 Equipment and Processing Blanks

A total of twenty-seven equipment and processing blanks were collected and submitted to EA Laboratories for chemical analysis. Blanks were collected by pouring deionized water over core collection equipment and sample processing equipment that had been decontaminated using the procedure outlined in Section 2.8, and placing the rinsate water in laboratory-prepared containers. Fifteen blanks were collected in the field (equipment blanks) and thirteen blanks were collected at the sample processing area (processing blanks). Blanks were analyzed for semivolatile organic compounds (SVOCs), priority pollutant metals, and TOC. Five of the 28 blanks were analyzed for organochlorine pesticides. Three samples were analyzed for PCB aroclors and congeners and PCT aroclors. Equipment blanks were sent to EA Laboratories via overnight delivery on the day of collection. Process blanks (which were performed at EA's

warehouse) were hand delivered to EA Laboratories on the day of collection. Chain-of-custody documentation was submitted with the equipment blanks (arriving via overnight delivery from the field) and with the processing blanks (hand carried from EA's processing area).

2.7 SAMPLES FOR OTHER TESTING PROGRAMS

Twenty sediment samples (15 samples from Scuffletown Creek and 5 samples from Eppinger and Russell) were submitted to the USEPA Environmental Research Lab–Narragansett (ERL-N) for toxicological testing. A list of sub-samples submitted to ERL-N is provided in Table 2-7. Sub-samples submitted to ERL-N from Scuffletown Creek were extracted from the 0-1 ft depth interval composites that were scheduled for the full suite of analytical testing. The 5 sub-samples from Eppinger and Russell were from the five stations scheduled for analytical testing. The sub-samples were removed from the homogenized sediment composite during sample processing and were transferred to jars supplied by EPA ERL-N. These samples were sent directly from EA to ERL-N at the completion of field activities.

2.8 DECONTAMINATION AND WASTE HANDLING PROCEDURES

Equipment that came into direct contact with sediment to be tested was decontaminated prior to deployment in the field to minimize cross-contamination. This included CAB core liners, core caps, stainless steel cutters, stainless steel catchers, and stainless steel processing equipment (spoons, knives, bowls, extruder, etc.). Nose cones and core catchers that were reused in the field were decontaminated on-board the sampling boat between stations. While performing the decontamination procedure, phthalate-free nitrile gloves were used to prevent phthalate contamination of the sampling equipment or the samples.

The decontamination procedure described below was used:

- Rinse equipment using clean tap or site water
- Wash and scrub with non-phosphate detergent (Alconox or other laboratory-grade detergent)
- Rinse with tap water
- Rinse with 10 percent nitric acid (HNO_3)
- Rinse with distilled or de-ionized water
- Rinse with methanol followed by hexane
- Rinse with distilled or de-ionized water

- Air dry (in area not adjacent to the decontamination area)
- Wrap equipment in aluminum foil, shiny side out

Waste liquids were contained during decontamination procedures and transferred to a 55-gallon drum for characterization and disposal at the end of the field effort.

2.9 SAMPLE CHAIN-OF-CUSTODY AND DOCUMENTATION

2.9.1 Field Logbook

A log of coring activities, station locations, water depths, and core recoveries were recorded in permanently bound logbooks in indelible ink. In addition to sampling information, personnel names, local weather conditions, and other information that impacted the field sampling program were recorded. Each page of the logbook (field and sample processing) was numbered, dated, and signed by the personnel entering information.

Copies of the log books were made during field activities and filed at EA's office in Sparks, MD. Full copies of the project logbooks are contained in Appendix A.

2.9.2 Numbering System

Two separate, but related sample numbering systems were used for this project. One applied to the cores, the other to the samples. The core numbering system was used to indicate which cores were collected from each station. The sample numbering system provided communication between the sample processing operation and the laboratories performing the desired analyses.

Core Numbering

Cores were numbered as follows:

CBC001-CORE1

where the first two characters denoted the site designation and the third character denoted whether the core was taken on the coarse (C) or fine (F) grid. The number indicated the station location within each site. CORE1, CORE2, etc., represented the multiple cores collected from some of the sites.

The site designation letters were:

CB = East of Campostella Bridge
ER = Eppinger and Russell
SF = Scuffletown Creek
SC = Scotts Creek

Sample Numbering

Composite samples taken from sediment cores collected at Scotts Creek, East of Campostella Bridge, and Eppinger and Russell were labeled as follows:

SCC001	(Scotts Creek, coarse grid example, station 001)
SCF001	(Scotts Creek, fine grid example, station 001)
CBC001	(East of Campostella Bridge, coarse grid example, station 001)
CBF001	(East of Campostella Bridge, fine grid example, station 001)
ERC001	(Eppinger and Russell, coarse grid example, station 001)
ERF001	(Eppinger and Russell, fine grid example, station 001),

where the site designation was the same as the core numbering system and the number indicated the station location within each site.

Samples collected from cores taken in Scuffletown Creek had a second field appended to indicate the depth interval of the sample:

SFC001-01 represented the 0-to-1 ft depth interval
SFC001-12 represented the 1-to-2 ft depth interval

Field Duplicate Numbering

Field duplicate samples were labeled as follows:

CBC001FD (Campostella example) or SFC001-01FD (Scuffletown example)

where the site designation was the same as the core numbering system and "FD" was appended to indicate that the sample was a field duplicate.

Blank Numbering

Equipment blanks, field blanks, and processing blanks were labeled, respectively, as follows:

EQB-*ddmmyy*
FDB-*ddmmyy*
PRB-*ddmmyy*

where the 2-digit day, month, and year of collection was designated within each sample ID.

2.9.3 Chain-of-Custody Records

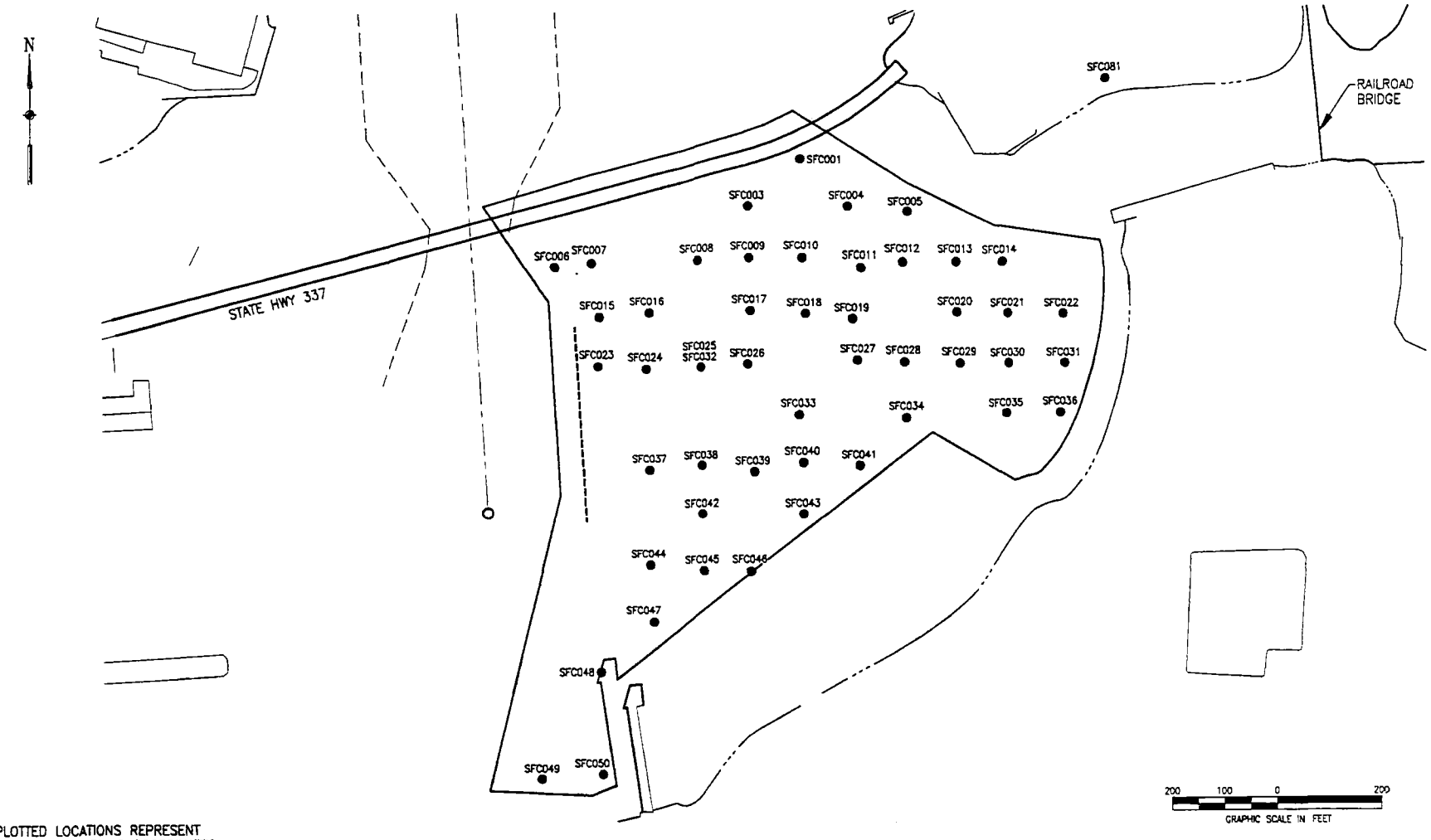
Sediment cores collected in the field were documented on a core-specific Chain-of-Custody (COC). The COC accompanied the cores to the sample processing facility at EA's offices in Sparks, MD. Sample processing personnel prepared a separate COC for sample submittal to EA Laboratories and the USEPA ERL-N. An example of EA Laboratories' Chain-of-Custody form is provided as Figure 5-1. Copies of project Chain-of-Custody forms are provided in Appendix D, with data validation reports.

2.10 CORE PHOTOGRAPHY AND LITHOLOGY

Twenty-nine cores collected at the previous Eppinger and Russell site were photographed and inspected for creosote deposits. The following stations were photographed and described:

- ERC 002, 003, 006, 007, and 009
- ERF 001-010, 012-025 (station 011 was submitted for chemical analysis)

Prior to photographing a core, the CAB liner was longitudinally cut on two opposite sides using a circular saw. The sediment was then sliced with a thin wire pulled through slices in the core liner. The core was carefully split in half longitudinally; one half was placed upon a white background next to a linear-foot scale. Core name and date of collection were written next to the core and the photograph was taken. An EA Geologist described the lithology of each core and produced a core log for each station. The photographs and core logs were submitted to the Norfolk District USACE on 20 May 1999. Copies of the lithology logs and color copies of the photographs are provided in Appendix A.



PLOTTED LOCATIONS REPRESENT
AVERAGED SAMPLING COORDINATES

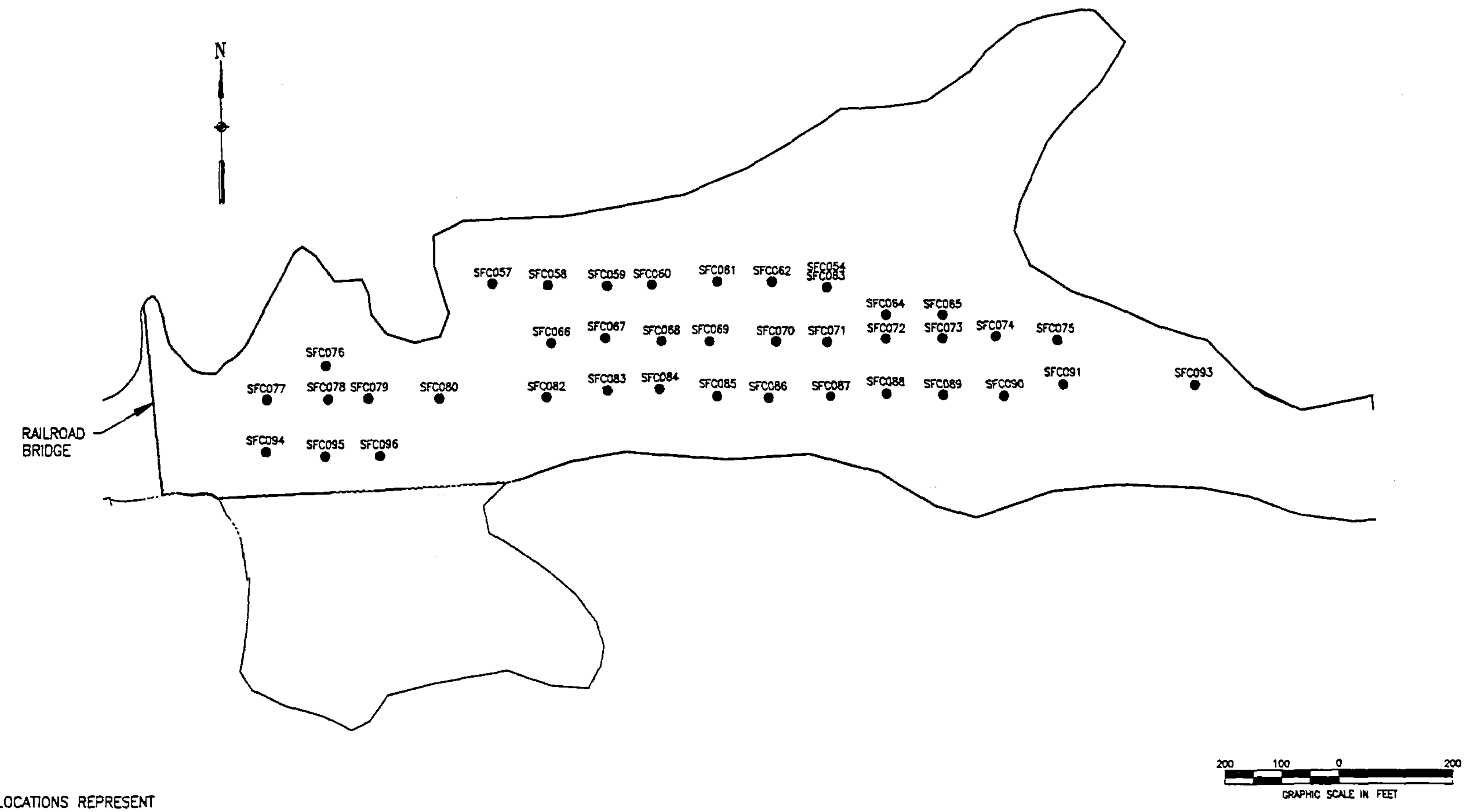
FILE: Q:\CAD\PROJECTS\61144G2\DS01\ACTUAL\FIG12B

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRGINIA

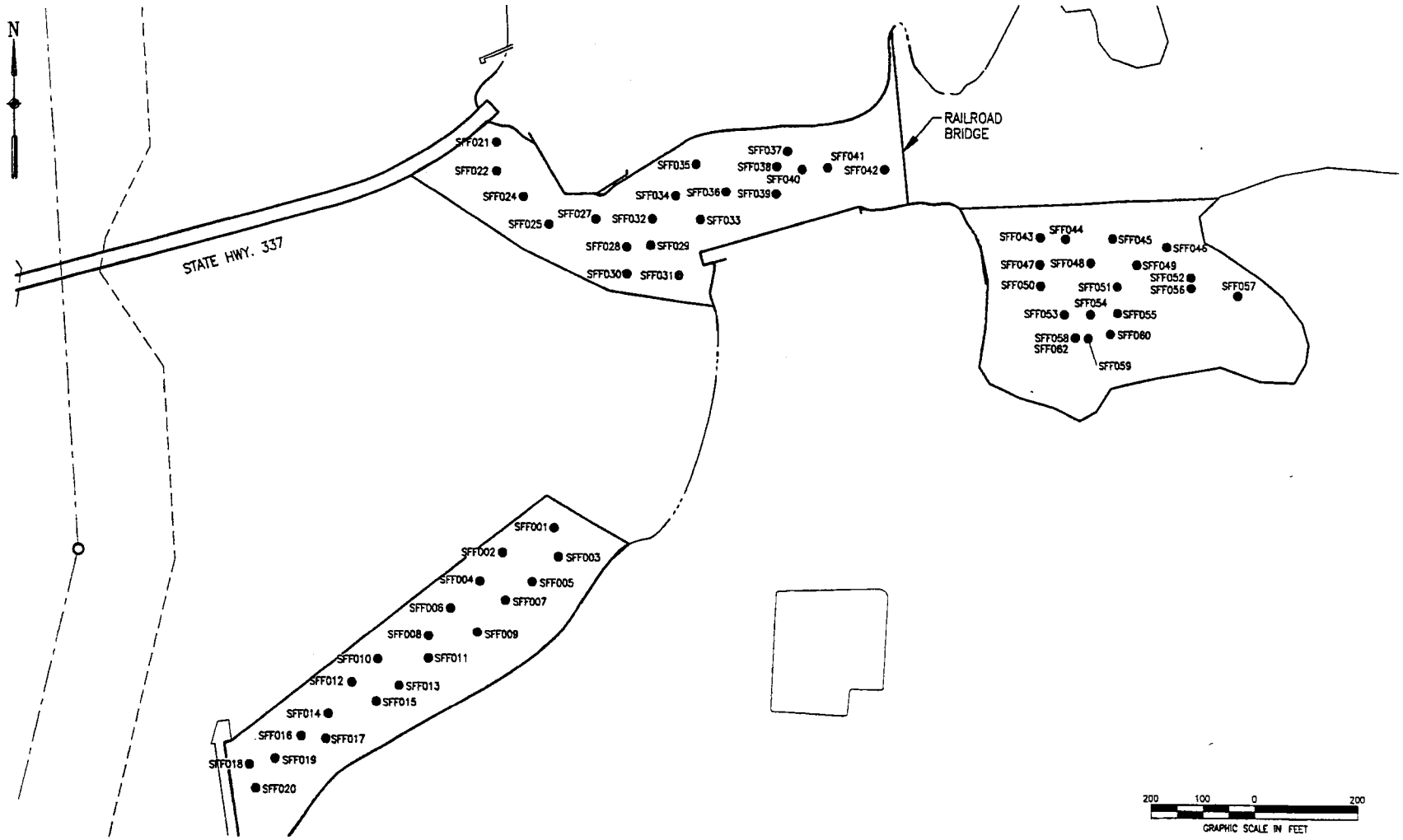
SAMPLING LOCATIONS AT
SCUFFLETOWN CREEK WEST OF RAILROAD BRIDGE
COARSE GRID.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
TW	WCM	6-23-99	61144.02	FIG12B
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
PAD	WWW	1"=200'	–	2-1A



PLOTTED LOCATIONS REPRESENT
AVERAGED SAMPLING COORDINATES

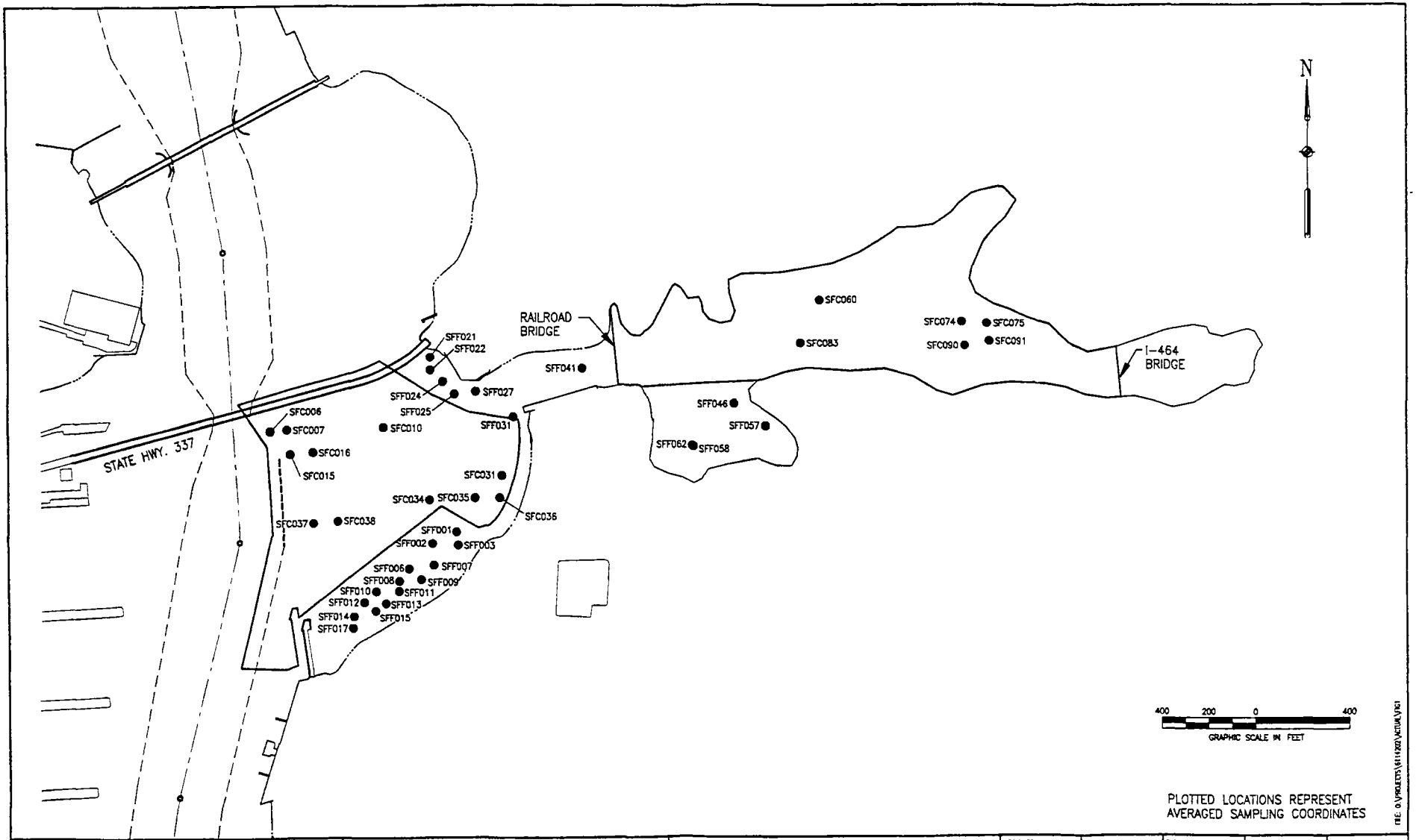
EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS AT SCUFFLETOWN CREEK EAST OF RAILROAD BRIDGE COARSE GRID.	DESIGNED BY TW	DRAWN BY WCM	DATE 6-23-99	PROJECT NO. 61144.02	FILE NAME FIG12A
			CHECKED BY PAD	PROJECT MGR. WWW	SCALE 1"-200'	DRAWING NO. -	FIGURE 2-1B



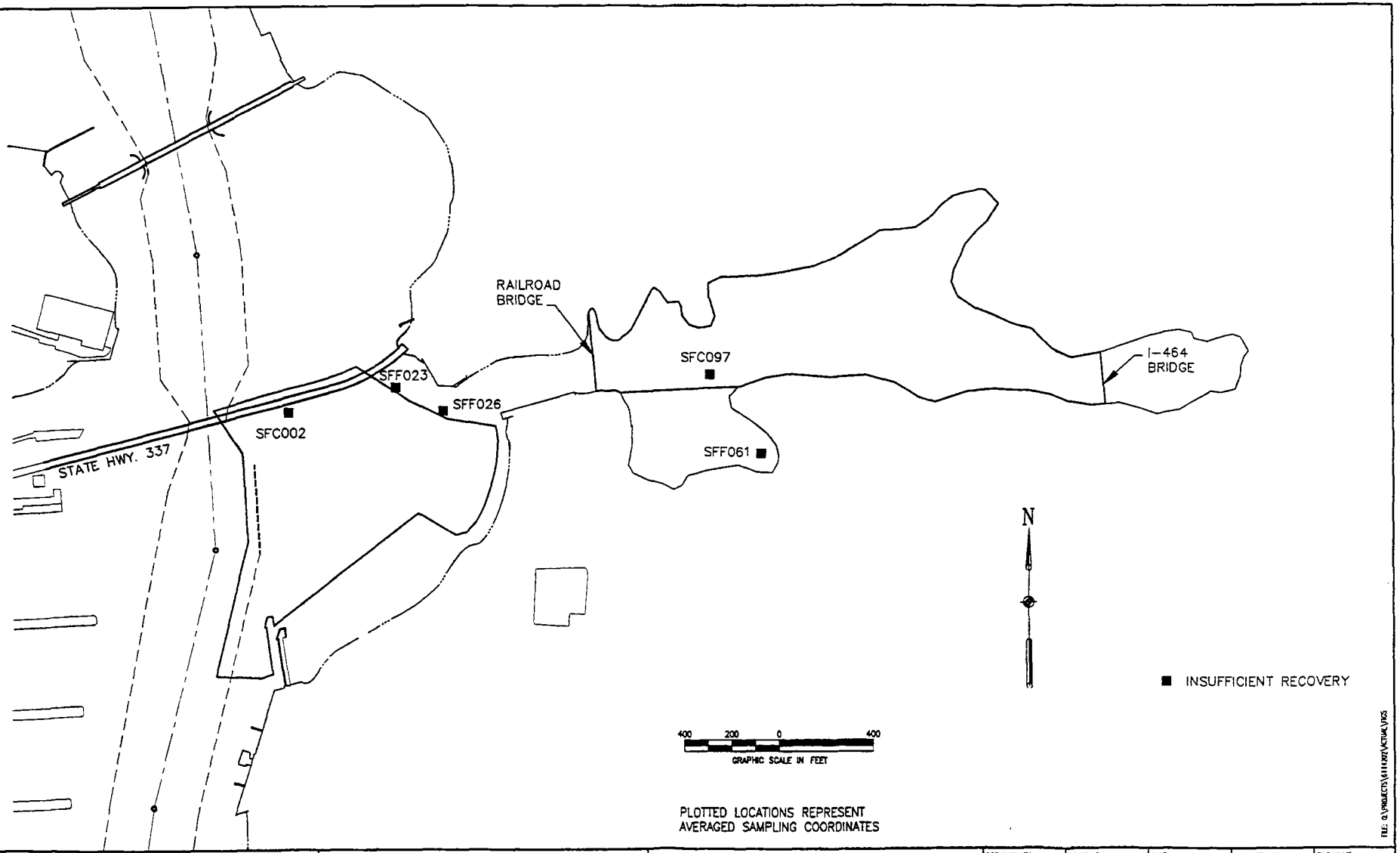
PLOTTED LOCATIONS REPRESENT AVERAGED SAMPLING COORDINATES

FILE: Q:\PROJECTS\61144Q2\001\ACTIVE\FIG11

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS IN SCUFFLETOWN CREEK–FINE GRID	DESIGNED BY: TW	DRAWN BY: WCM	DATE: 6-23-99	PROJECT NO.: 61144.02	FILE NAME: FIG11
			CHECKED BY: PAD	PROJECT MGR.: CEF	SCALE: 1"=200'	DRAWING NO.: -	FIGURE: 2-1C



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS IN SCUFFLETOWN CREEK WITH INSUFFICIENT SEDIMENT RECOVERY FROM 1-2FT. DEPTH	DESIGNED BY: TW	DRAWN BY: WCM	DATE: 6-23-99	PROJECT NO.: 61142.02	FILE NAME: FIG1
			CHECKED BY: PAD	PROJECT MGR.: CEF	SCALE: 1"=400'	DRAWING NO.: -	FIGURE: 2-1D



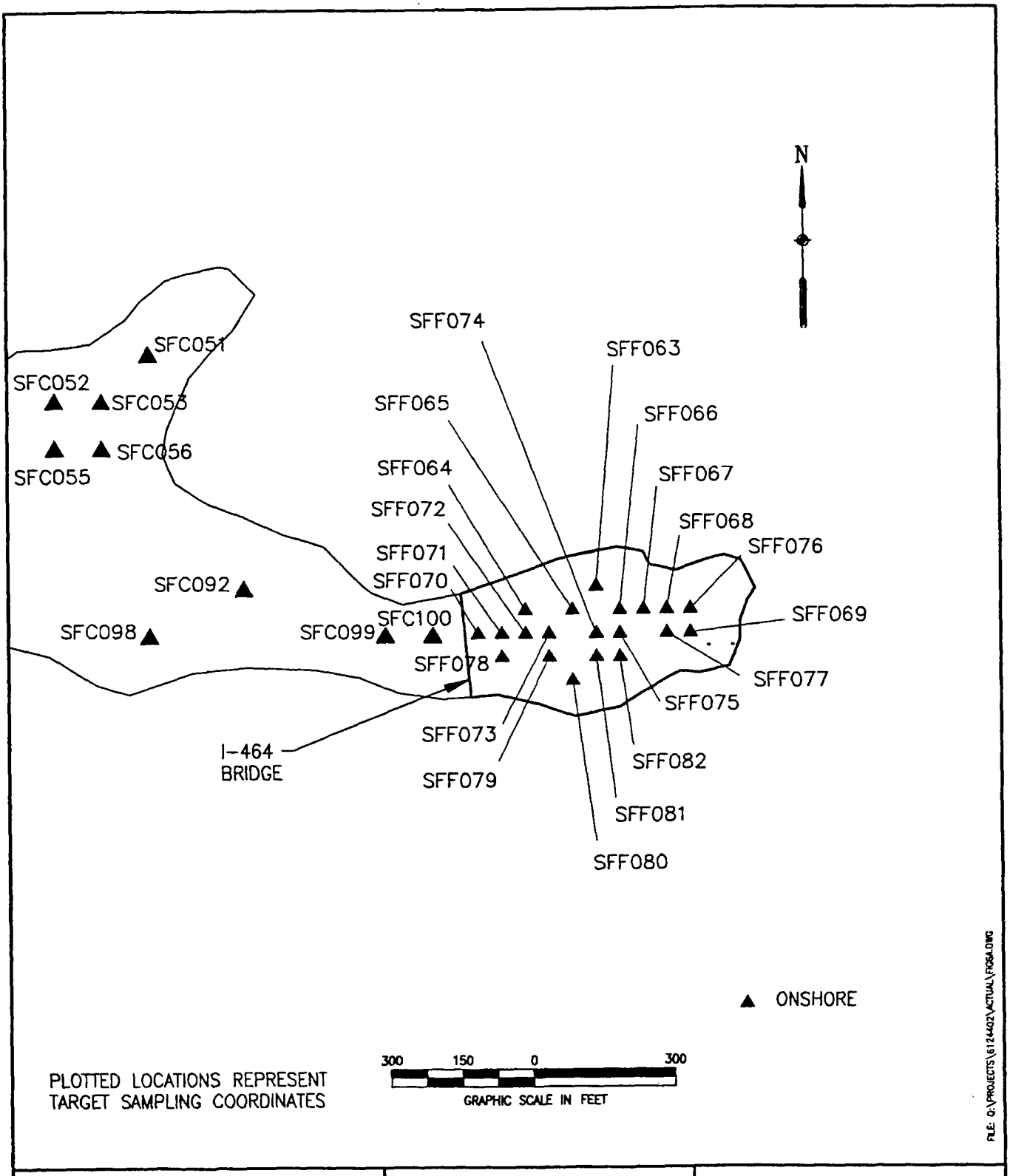
EA ENGINEERING, SCIENCE, AND TECHNOLOGY

ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRGINIA

STATION LOCATIONS IN SCUFFLETOWN CREEK, WITH NO SEDIMENT RECOVERY

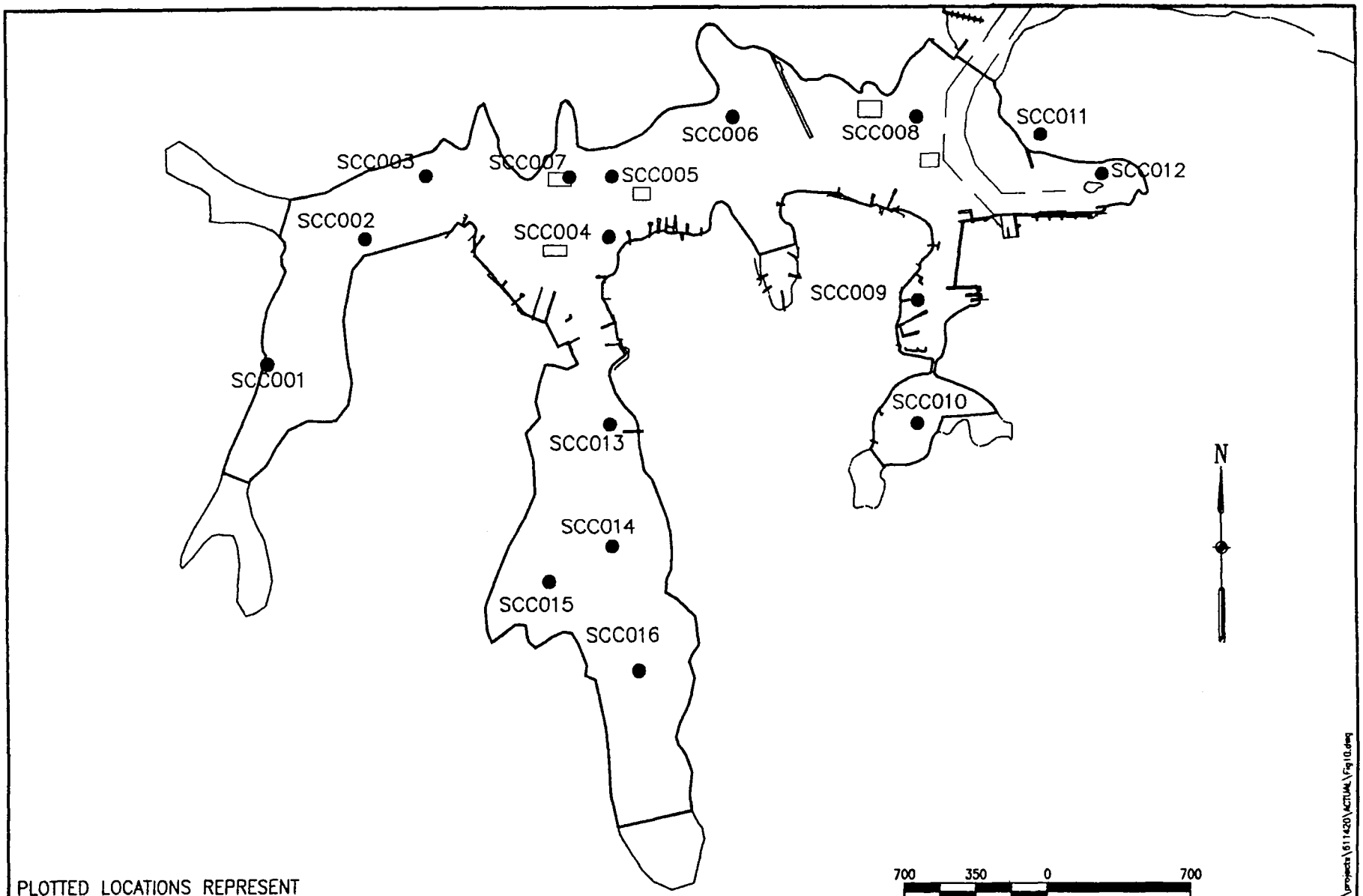
DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
TW	WCM	2-15-99	61142.02	FIG5
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
PAD	CEF	1"=400'	–	2-1E

FILE: Q:\PROJECTS\61142\02\ACTIVE\FIG5



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	STATION LOCATIONS IN SCUFFLETOWN CREEK LOCATED ON SHORE

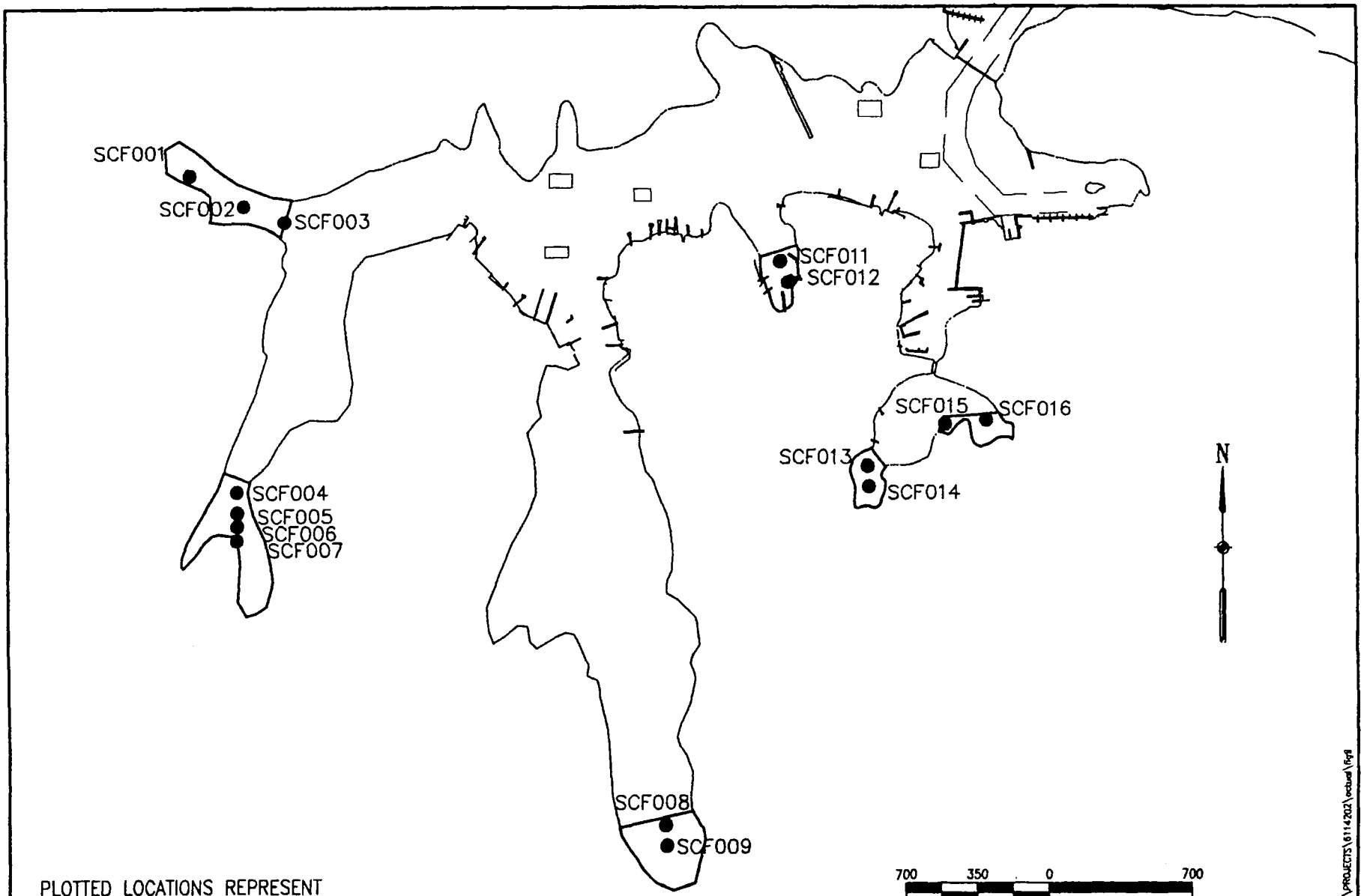
PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
CEF	TW	WCM	PAD	1"=300'	2-18-99	61142.02	2-1F



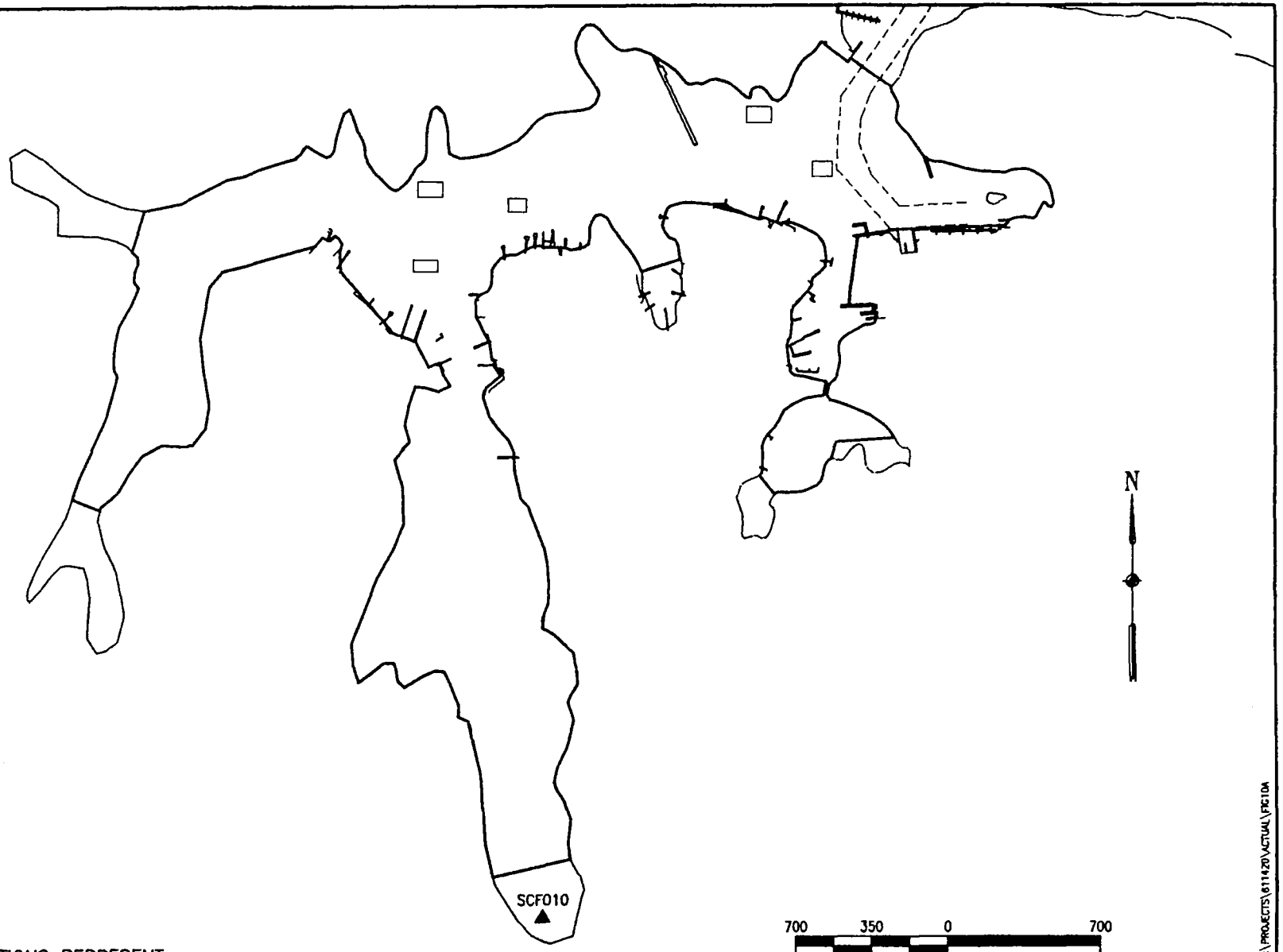
PLOTTED LOCATIONS REPRESENT AVERAGED SAMPLING COORDINATES

FILE: q:\projects\61142O\ACTUAL\Fig10.dwg

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS IN SCOTTS CREEK - COARSE GRID	DESIGNED BY TW	DRAWN BY WCM	DATE 2-18-99	PROJECT NO. 61142.02
			CHECKED BY PAD	PROJECT MGR. CEF	SCALE 1"=700'	FIGURE 2-2A



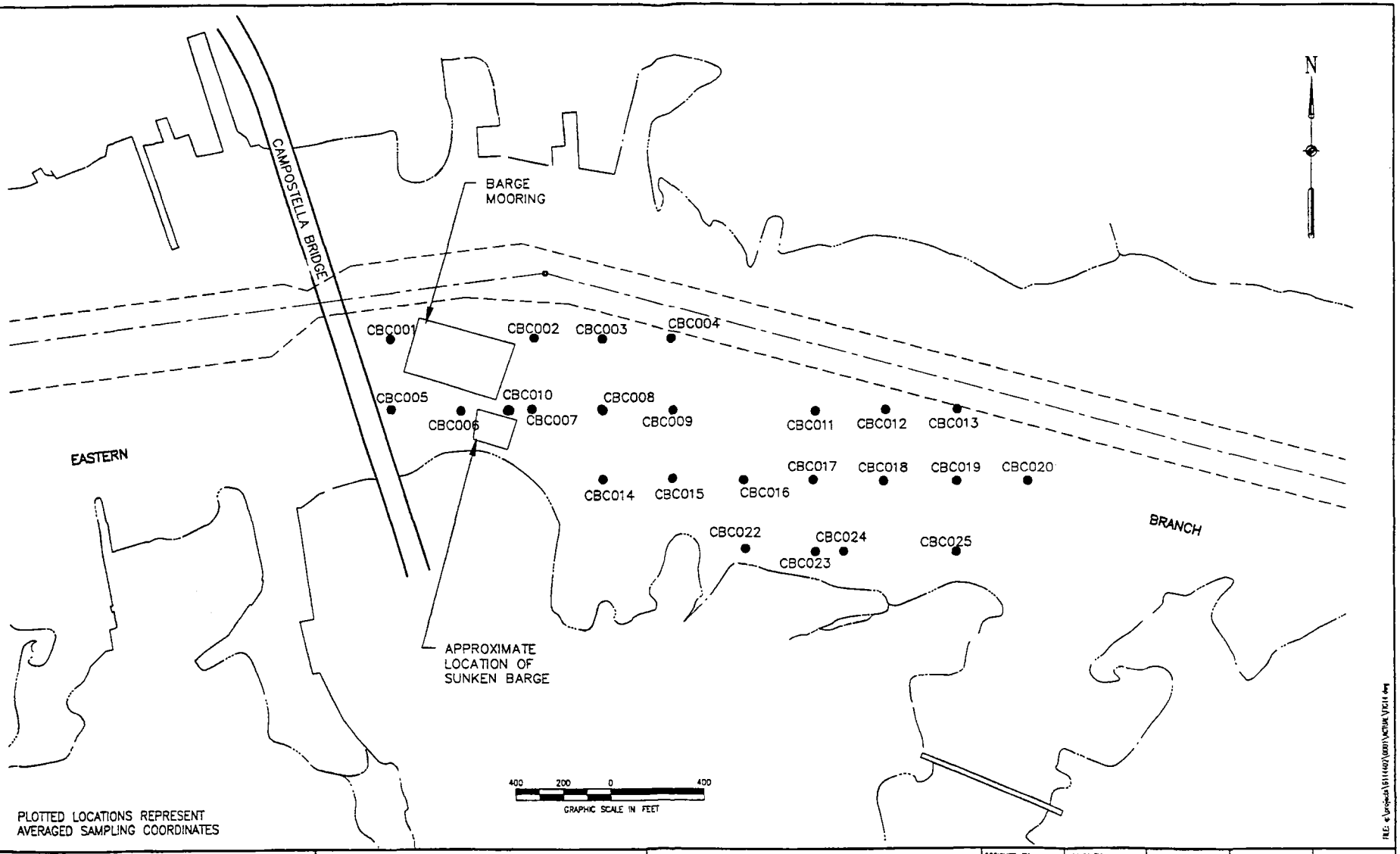
EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS IN SCOTTS CREEK – FINE GRID	DESIGNED BY TW	DRAWN BY WCM	DATE 2-18-99	PROJECT NO. 61142.02
			CHECKED BY PAD	PROJECT MGR. CEF	SCALE 1"=700'	FIGURE 2-2B



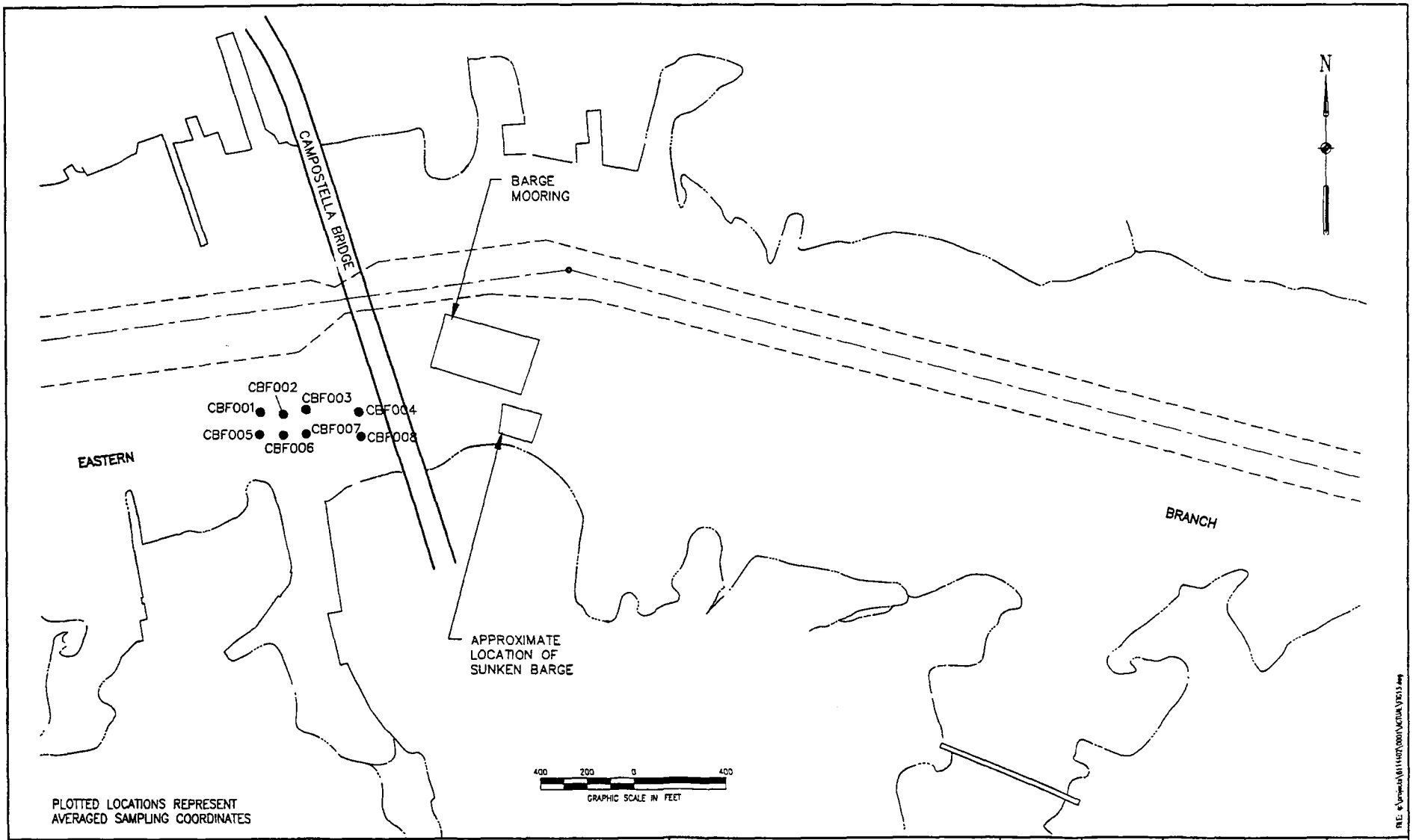
PLOTTED LOCATIONS REPRESENT
TARGET SAMPLING COORDINATES

FILE: G:\PROJECTS\61142\02\ACTUAL\FIG10A

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	STATION LOCATIONS IN SCOTTS CREEK WITH NO SEDIMENT RECOVERY	DESIGNED BY TW	DRAWN BY WCM	DATE 6-24-99	PROJECT NO. 61142.02
			CHECKED BY PAD	PROJECT MGR. CEF	SCALE 1"=700'	FIGURE 2-2C



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS AT EAST OF CAMPOSTELLA BRIDGE – COARSE GRID	DESIGNED BY: TW	DRAWN BY: WCM	DATE: FEB 1999	PROJECT NO.: 61142.02	FILE NAME: FIG14
			CHECKED BY: PAD	PROJECT MGR.: CEF	SCALE: 1"=400'	DRAWING NO.: –	FIGURE: 2-3A

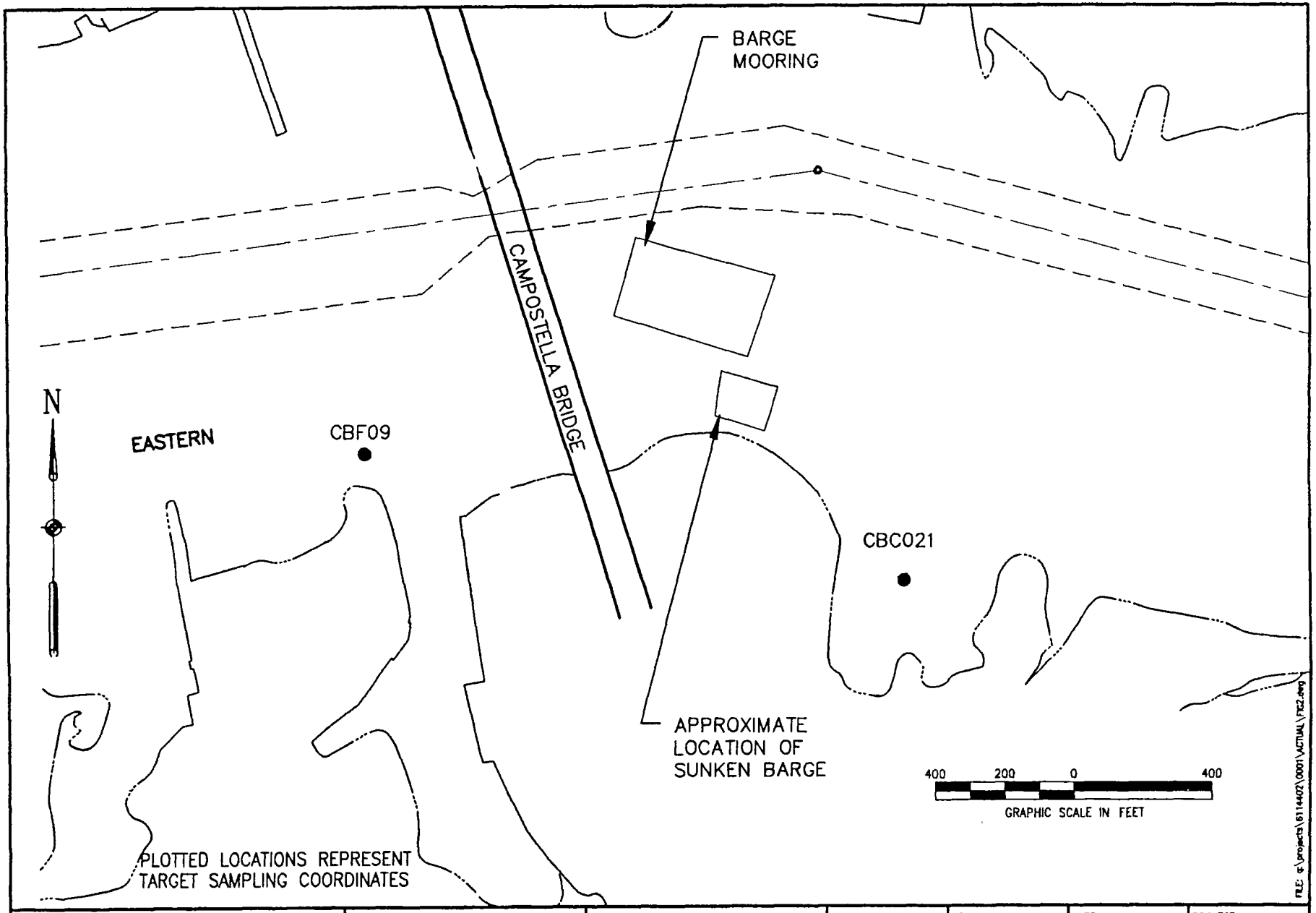


EA ENGINEERING, SCIENCE, AND TECHNOLOGY

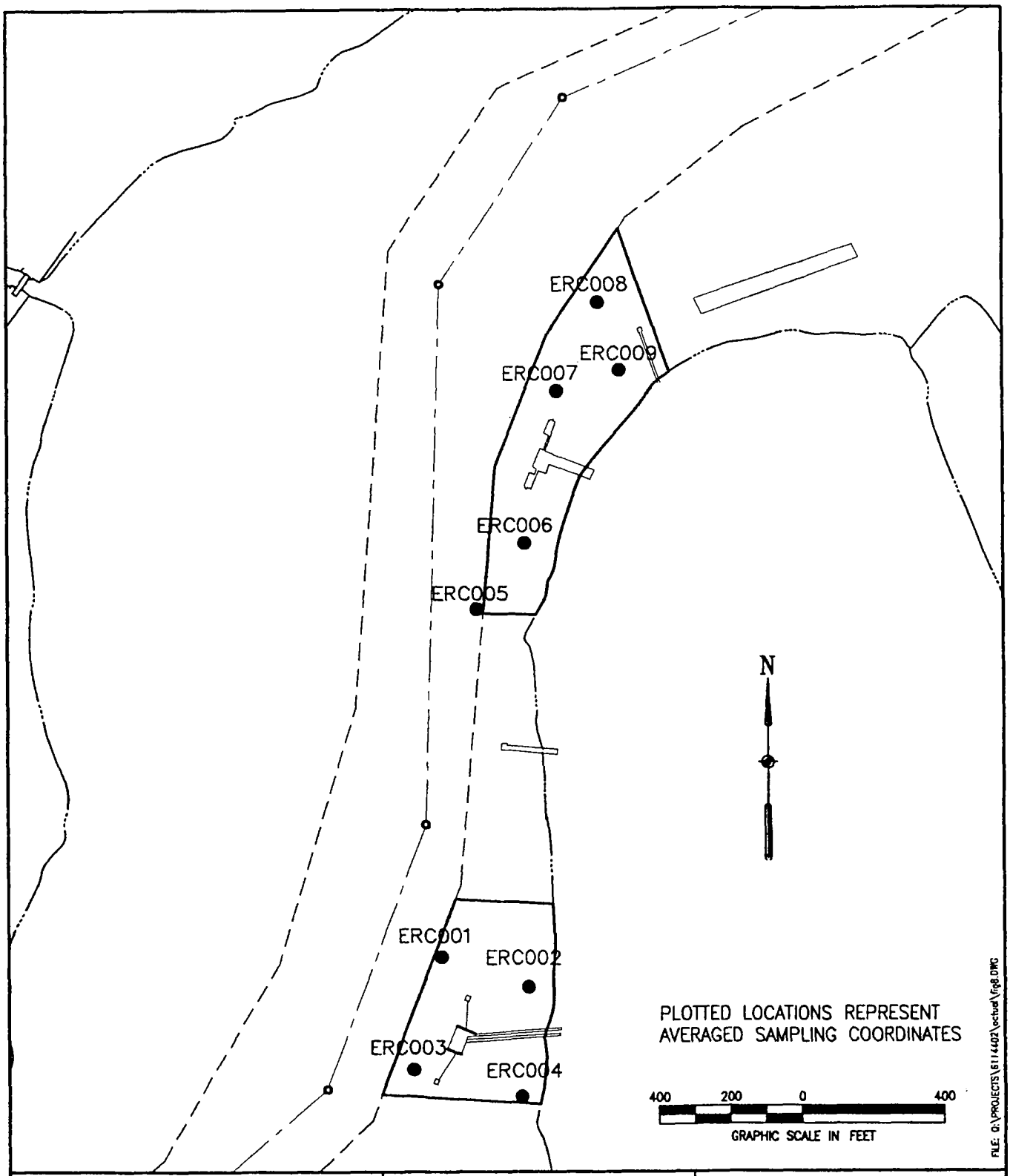
ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRGINIA

SAMPLING LOCATIONS EAST OF CAMPOSTELLA BRIDGE - FINE GRID

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
TW	WCM	FEB 1999	61142.02	FIG13
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
PAD	CEF	1"=400'	-	2-3B



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	STATION LOCATIONS EAST OF CAMPOSTELLA BRIDGE WITH NO SEDIMENT RECOVERY	DESIGNED BY TW	DRAWN BY WCM	DATE 6-23-99	PROJECT NO. 61142.02
			CHECKED BY PAD	PROJECT MGR. CEF	SCALE 1"=400'	FIGURE 2-3C

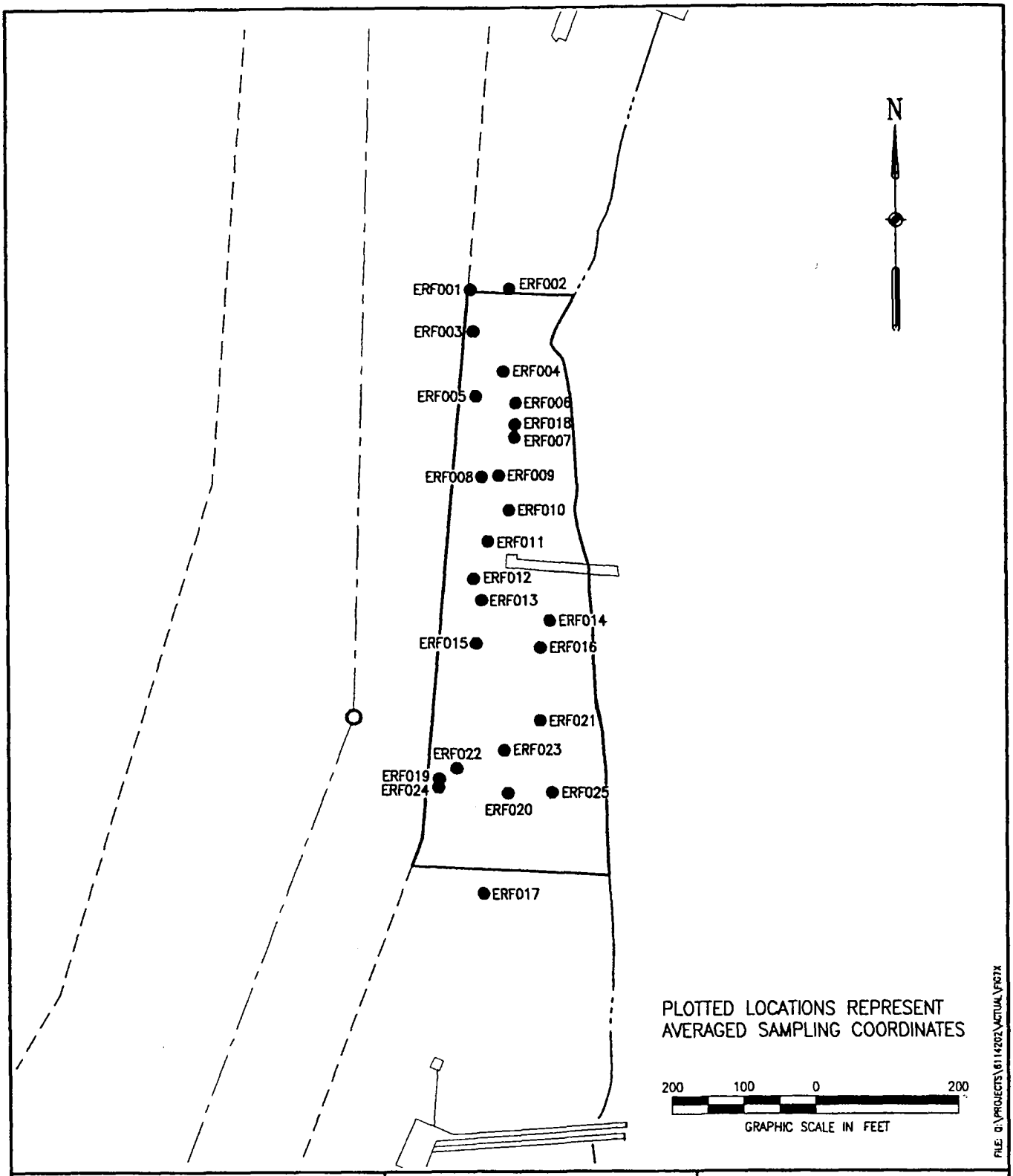


EA ENGINEERING, SCIENCE, AND TECHNOLOGY

ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRINIA

SAMPLING LOCATIONS AT EPPINGER & RUSSELL – COARSE GRID

PROJECT MGR	DESIGNED BY	DRAWN BY #	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
CEF	TW	WCM	PAD	1"=400'	2-18-99	61142.02	2-4A



EA ENGINEERING, SCIENCE, AND TECHNOLOGY

ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRGINIA

SAMPLING LOCATIONS AT
EPPINGER & RUSSEL – FINE GRID

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
CEF	TW	MSM	PAD	1"=200'	6-24-99	61142.02	2-4B

TABLE 2-1. SUMMARY OF ONSHORE STATIONS AND STATIONS WITH INSUFFICIENT SEDIMENT RECOVERY

Stations located Onshore	Stations with Insufficient Recovery	Scuffletown Creek Stations with Insufficient 1-2ft Recovery
Scuffletown Creek	**Scuffletown Creek**	SFF001
SFF063	SFF023	SFF002
SFF064	SFF026	SFF003
SFF065	SFF061	SFF004
SFF066	SFC002	SFF006
SFF067	SFC097	SFF007
SFF068		SFF008
SFF069	**East of Campostella**	SFF009
SFF070	CBF009	SFF010
SFF071	CBC021	SFF011
SFF072		SFF012
SFF073		SFF013
SFF074		SFF014
SFF075		SFF015
SFF076		SFF017
SFF077		SFF021
SFF078		SFF022
SFF079		SFF024
SFF080		SFF025
SFF081		SFF027
SFC051		SFF031
SFC052		SFF041
SFC053		SFF046
SFC055		SFF058
SFC056		SFF062
SFC092		SFC006
SFC098		SFC015
SFC099		SFC016
SFC100		SFC031
		SFC034
Scotts Creek		SFC035
SCF 010		SFC036
		SFC037
		SFC038
		SFC060
		SFC074
		SFC075
		SFC083
		SFC090
		SFC091

TABLE 2-2. SCUFFLETOWN CREEK:
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite (ft)
Fine Grid						
SFF001	3,460,855	12,130,777	2	Gravity	2	0 - 1.0
SFF002	3,460,806	12,130,676	3	Gravity	2	0 - 1.0
SFF003	3,460,798	12,130,785	3	Gravity	2	0 - 1.0
SFF004	3,460,749	12,130,632	4	Gravity	2	0 - 1.0
SFF005	3,460,748	12,130,734	3	Gravity	2	0 - 1.5
SFF006	3,460,696	12,130,574	3	Gravity	2	0 - 1.0
SFF007	3,460,712	12,130,682	3	Gravity	2	0 - 1.0
SFF008	3,460,643	12,130,532	1	Gravity	2	0 - 1.0
SFF009	3,460,650	12,130,627	2	Gravity	2	0 - 1.0
SFF010	3,460,599	12,130,432	2	Gravity	5	0 - 1.0
SFF011	3,460,600	12,130,531	2	Gravity	2	0 - 1.0
SFF012	3,460,553	12,130,382	2	Gravity	2	0 - 1.0
SFF013	3,460,547	12,130,474	2	Gravity	2	0 - 1.0
SFF014	3,460,492	12,130,336	3	Gravity	2	0 - 1.0
SFF015	3,460,515	12,130,429	1	Gravity	2	0 - 1.0
SFF016	3,460,448	12,130,283	9	Gravity	2	0 - 1 4
SFF017	3,460,442	12,130,331	1	Gravity	2	0 - 1.0
SFF018	3,460,393	12,130,182	11	Gravity	2	0 - 2.0
SFF019	3,460,405	12,130,232	9	Gravity	2	0 - 2.0
SFF020	3,460,347	12,130,194	9	Gravity	5	0 - 2.0
SFF021	3,461,610	12,130,667	3	Gravity	2	0 - 1.0
SFF022	3,461,554	12,130,667	5	Gravity	2	0 - 1.0
SFF024	3,461,504	12,130,720	5	Gravity	2	0 - 1.0
SFF025	3,461,450	12,130,769	2	Gravity	2	0 - 1.0
SFF027	3,461,460	12,130,860	3	Gravity	2	0 - 1.0
SFF028	3,461,406	12,130,919	7	Gravity	2	0 - 2.0
SFF029	3,461,409	12,130,966	6	Gravity	2	0 - 1.5
SFF030	3,461,353	12,130,919	6	Gravity	5	0 - 1.7
SFF031	3,461,351	12,131,022	7	Gravity	2	0 - 1.0
SFF032	3,461,460	12,130,969	7	Gravity	2	0 - 2.0
SFF033	3,461,458	12,131,066	5	Gravity	2	0 - 1 8
SFF034	3,461,506	12,131,016	4	Gravity	2	0 - 1.6
SFF035	3,461,566	12,131,057	3	Gravity	2	0 - 2.0
SFF036	3,461,512	12,131,116	6	Gravity	2	0 - 1.8
SFF037	3,461,591	12,131,236	4	Gravity	2	0 - 2.0
SFF038	3,461,562	12,131,216	5	Gravity	2	0 - 1.7
SFF039	3,461,508	12,131,214	5	Gravity	2	0 - 2 0
SFF040	3,461,556	12,131,265	6	Gravity	5	0 - 1 7
SFF041	3,461,560	12,131,315	3	Gravity	2	0 - 1.0
SFF042	3,461,555	12,131,426	2	Gravity	2	0 - 1.8
SFF043	3,461,424	12,131,726	1	Gravity	2	0 - 2 0
SFF044	3,461,421	12,131,775	2	Gravity	2	0 - 1.9
SFF045	3,461,421	12,131,869	2	Gravity	2	0 - 1 5
SFF046	3,461,405	12,131,975	2	Gravity	2	0 - 1.0
SFF047	3,461,371	12,131,725	1	Gravity	2	0 - 2 0
SFF048	3,461,374	12,131,824	1	Gravity	2	0 - 2 0
SFF049	3,461,370	12,131,917	1	Gravity	2	0 - 2.0
SFF050	3,461,329	12,131,726	1	Gravity	5	0 - 2.0
SFF051	3,461,327	12,131,878	2	Gravity	2	0 - 2.0
SFF052	3,461,345	12,132,021	1	Gravity	2	0 - 2.0

Coordinates averaged for stations with 2 or more cores

TABLE 2-2. SCUFFLETOWN CREEK:
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite (ft)
SFF053	3,461,273	12,131,772	1	Gravity	2	0 - 2.0
SFF054	3,461,274	12,131,824	1	Gravity	2	0 - 2.0
SFF055	3,461,275	12,131,878	1	Gravity	2	0 - 1.3
SFF056	3,461,325	12,132,022	1	Gravity	2	0 - 2.0
SFF057	3,461,310	12,132,112	1	Gravity	2	0 - 2.0
SFF058	3,461,224	12,131,800	1	Gravity	2	0 - 1.0
SFF059	3,461,226	12,131,819	1	Gravity	2	0 - 2.0
SFF060	3,461,234	12,131,863	1	Gravity	5	0 - 2.0
SFF062	3,461,228	12,131,794	1	Gravity	2	0 - 1.0
Coarse Grid						
SFC001	3,461,500	12,130,464	9	Gravity	2	0 - 2.0
SFC003	3,461,408	12,130,362	15	Gravity	2	0 - 2.0
SFC004	3,461,407	12,130,554	7	Gravity	2	0 - 2.0
SFC005	3,461,397	12,130,668	4	Gravity	2	0 - 2.0
SFC006	3,461,293	12,129,983	43	Gravity	2	0 - 1.5
SFC007	3,461,300	12,130,054	24	Gravity	2	0 - 2.0
SFC008	3,461,304	12,130,263	11	Gravity	2	0 - 2.0
SFC009	3,461,308	12,130,363	12	Gravity	2	0 - 2.0
SFC010	3,461,308	12,130,466	7	Gravity	5	0 - 2.0
SFC011	3,461,289	12,130,578	7	Gravity	2	0 - 2.0
SFC012	3,461,299	12,130,659	9	Gravity	2	0 - 2.0
SFC013	3,461,300	12,130,762	9	Gravity	2	0 - 2.0
SFC014	3,461,299	12,130,852	8	Gravity	2	0 - 2.0
SFC015	3,461,195	12,130,067	34	Gravity	2	0 - 1.0
SFC016	3,461,203	12,130,164	10	Gravity	2	0 - 1.0
SFC017	3,461,205	12,130,364	11	Gravity	2	0 - 2.0
SFC018	3,461,199	12,130,471	8	Gravity	2	0 - 2.0
SFC019	3,461,189	12,130,561	6	Gravity	2	0 - 2.0
SFC020	3,461,201	12,130,761	2	Gravity	5	0 - 2.0
SFC021	3,461,198	12,130,861	4	Gravity	2	0 - 1.8
SFC022	3,461,197	12,130,968	6	Gravity	2	0 - 1.8
SFC023	3,461,099	12,130,064	41	Gravity	2	0 - 2.0
SFC024	3,461,094	12,130,158	11	Gravity	2	0 - 1.5
SFC025	3,461,096	12,130,267	8	Gravity	2	0 - 1.5
SFC026	3,461,102	12,130,358	6	Gravity	2	0 - 2.0
SFC027	3,460,609	12,130,569	4	Gravity	2	0 - 2.0
SFC028	3,461,104	12,130,660	4	Gravity	2	0 - 1.5
SFC029	3,461,102	12,130,767	4	Gravity	2	0 - 2.0
SFC030	3,461,101	12,130,861	2	Gravity	5	0 - 2.0
SFC031	3,461,101	12,130,971	3	Gravity	2	0 - 1.0
SFC032	3,461,100	12,130,262	8	Gravity	2	0 - 2.0
SFC033	3,461,002	12,130,458	4	Gravity	2	0 - 2.0
SFC034	3,460,995	12,130,663	3	Gravity	2	0 - 1.0
SFC035	3,461,003	12,130,857	3	Gravity	2	0 - 1.3
SFC036	3,460,504	12,130,961	3	Gravity	2	0 - 1.0
SFC037	3,460,897	12,130,164	11	Gravity	2	0 - 1.5
SFC038	3,460,905	12,130,268	10	Gravity	2	0 - 1.3
SFC039	3,460,892	12,130,370	8	Gravity	2	0 - 2.0
SFC040	3,460,909	12,130,465	4	Gravity	5	0 - 2.0
SFC041	3,460,903	12,130,573	4	Gravity	2	0 - 2.0
SFC042	3,460,811	12,130,268	10	Gravity	2	0 - 2.0

Coordinates averaged for stations with 2 or more cores

TABLE 2-2. SCUFFLETOWN CREEK:
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite (ft)
SFC043	3,460,810	12,130,465	4	Gravity	2	0 - 2.0
SFC044	3,460,712	12,130,164	20	Gravity	2	0 - 2.0
SFC045	3,460,699	12,130,270	10	Gravity	2	0 - 2.0
SFC046	3,460,698	12,130,362	2	Gravity	2	0 - 2.0
SFC047	3,460,600	12,130,170	22	Gravity	2	0 - 2.0
SFC048	3,460,503	12,130,066	27	Gravity	2	0 - 2.0
SFC049	3,460,295	12,129,951	40	Gravity	2	0 - 2.0
SFC050	3,460,304	12,130,068	29	Gravity	5	0 - 2.0
SFC054	3,461,851	12,132,660	1	Gravity	2	0 - 1.8
SFC057	3,461,859	12,132,056	1	Gravity	5	0 - 2.0
SFC058	3,461,856	12,132,155	1	Gravity	2	0 - 2.0
SFC059	3,461,855	12,132,260	1	Gravity	2	0 - 2.0
SFC060	3,461,857	12,132,340	1	Gravity	5	0 - 1.0
SFC061	3,461,861	12,132,458	1	Gravity	2	0 - 2.0
SFC062	3,461,860	12,132,556	1	Gravity	2	0 - 2.0
SFC063	3,461,850	12,132,653	1	Gravity	2	0 - 2.0
SFC064	3,461,800	12,132,756	2	Hand	2	0 - 2.0
SFC065	3,461,800	12,132,856	2	Hand	2	0 - 2.0
SFC066	3,461,753	12,132,161	1	Gravity	2	0 - 2.0
SFC067	3,461,762	12,132,256	1	Gravity	2	0 - 2.0
SFC068	3,461,756	12,132,357	1	Gravity	2	0 - 2.0
SFC069	3,461,754	12,132,444	1	Gravity	2	0 - 2.0
SFC070	3,461,754	12,132,562	1	Gravity	5	0 - 2.0
SFC071	3,461,753	12,132,653	1	Gravity	2	0 - 2.0
SFC072	3,461,758	12,132,756	2	Hand	2	0 - 1.5
SFC073	3,461,758	12,132,856	2	Hand	2	0 - 2.0
SFC074	3,461,761	12,132,950	3	Hand	2	0 - 1.0
SFC075	3,461,754	12,133,058	3	Hand	2	0 - 1.2
SFC076	3,461,716	12,131,761	2	Gravity	2	0 - 2.0
SFC077	3,461,656	12,131,657	1	Gravity	2	0 - 2.0
SFC078	3,461,656	12,131,765	2	Gravity	2	0 - 2.0
SFC079	3,461,658	12,131,835	2	Gravity	2	0 - 2.0
SFC080	3,461,656	12,131,961	2	Gravity	5	0 - 1.5
SFC081	3,461,656	12,131,055	1	Gravity	2	0 - 2.0
SFC082	3,461,657	12,132,151	1	Gravity	2	0 - 2.0
SFC083	3,461,669	12,132,259	1	Gravity	2	0 - 1.0
SFC084	3,461,671	12,132,352	1	Gravity	2	0 - 1.0
SFC085	3,461,657	12,132,457	1	Gravity	2	0 - 1.0
SFC086	3,461,654	12,132,548	1	Gravity	2	0 - 2.0
SFC087	3,461,656	12,132,657	1	Gravity	2	0 - 2.0
SFC088	3,461,660	12,132,756	2	Hand	2	0 - 1.8
SFC089	3,461,658	12,132,856	2	Hand	2	0 - 2.0.
SFC090	3,461,655	12,132,963	2	Hand	5	0 - 1.0
SFC091	3,461,675	12,133,068	2	Hand	2	0 - 1.0
SFC093	3,461,673	12,133,303	1	Hand	2	0 - 1.5
SFC094	3,461,563	12,131,655	2	Gravity	2	0 - 1.9
SFC095	3,461,555	12,131,759	1	Gravity	2	0 - 2.0
SFC096	3,461,556	12,131,855	1	Gravity	2	0 - 2.0

Coordinates averaged for stations with 2 or more cores

TABLE 2-3. SCOTTS CREEK
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite (ft)
Fine Grid						
SCF001	3,475,155	12,118,280	2	Hand	2	0 - 1.0
SCF002	3,475,001	12,118,535	1	Gravity	2	0 - 1.0
SCF003	3,474,923	12,118,740	1	Gravity	1	0 - 2.0
SCF004	3,473,611	12,118,500	1	Hand	1	0 - 1.5
SCF005	3,473,510	12,118,502	2	Hand	1	0 - 2.0
SCF006	3,473,445	12,118,502	2	Hand	1	0 - 1.8
SCF007	3,473,375	12,118,500	2	Hand	1	0 - 2.0
SCF008	3,471,988	12,120,595	2	Hand	2	0 - 1.0
SCF009	3,471,888	12,120,596	2	Hand	1	0 - 1.7
SCF011	3,474,728	12,121,165	1	Gravity	1	0 - 2.0
SCF012	3,474,626	12,121,200	1	Gravity	1	0 - 2.0
SCF013	3,473,729	12,121,589	1	Hand	1	0 - 1.5
SCF014	3,473,633	12,121,597	1	Hand	2	0 - 1.5
SCF015	3,473,930	12,121,967	2	Hand	1	0 - 1.5
SCF016	3,473,950	12,122,167	1	Hand	1	0 - 1.7
Coarse Grid						
SCC001	3,474,231	12,118,656	1	Gravity	1	0 - 2.0
SCC002	3,474,836	12,119,137	1	Gravity	3	0 - 2.0
SCC003	3,475,145	12,119,434	1	Gravity	1	0 - 2.0
SCC004	3,474,840	12,120,330	1	Gravity	1	0 - 2.0
SCC005	3,475,137	12,120,345	1	Gravity	1	0 - 2.0
SCC006	3,475,431	12,120,935	1	Gravity	1	0 - 0.8
SCC007	3,475,136	12,120,136	2	Gravity	1	0 - 2.0
SCC008	3,475,432	12,121,834	3	Gravity	1	0 - 2.0
SCC009	3,474,534	12,121,841	3	Gravity	1	0 - 0.9
SCC010	3,473,935	12,121,836	1	Gravity	1	0 - 2.0
SCC011	3,475,340	12,122,439	2	Hand	2	0 - 1.5
SCC012	3,475,145	12,122,738	2	Hand	1	0 - 1.8
SCC013	3,473,934	12,120,331	1	Gravity	1	0 - 1.7
SCC014	3,473,340	12,120,339	1	Gravity	1	0 - 2.0
SCC015	3,473,168	12,120,032	1	Gravity	1	0 - 2.0
SCC016	3,472,735	12,120,469	1	Gravity	1	0 - 2.0

Coordinates averaged for stations with 2 or more cores

TABLE 2-4. EAST OF CAMPOSTELLA BRIDGE:
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite (ft)
Fine Grid						
CBF001	3,472,645	12,136,485	15	Gravity	1	0 - 1.7
CBF002	3,472,636	12,136,583	31	Gravity	1	0 - 2.0
CBF003	3,472,655	12,136,681	23	Gravity	1	0 - 2.0
CBF004	3,472,643	12,136,905	17	Gravity	1	0 - 2.0
CBF005	3,472,544	12,136,482	10	Gravity	3	0 - 1.5
CBF006	3,472,545	12,136,583	10	Gravity	1	0 - 2.0
CBF007	3,472,549	12,136,680	31	Gravity	1	0 - 2.0
CBF008	3,472,536	12,136,914	28	Gravity	1	0 - 2.0
Coarse Grid						
CBC001	3,472,977	12,137,152	14	Gravity	1	0 - 2.0
CBC002	3,472,981	12,137,757	14	Gravity	1	0 - 1.8
CBC003	3,472,977	12,138,045	17	Gravity	1	0 - 2.0
CBC004	3,472,980	12,138,341	19	Gravity	1	0 - 2.0
CBC005	3,472,678	12,137,156	8	Gravity	1	0 - 1.5
CBC006	3,472,670	12,137,450	7	Gravity	1	0 - 1.3
CBC007	3,472,678	12,137,749	8	Gravity	1	0 - 2.0
CBC008	3,472,674	12,138,045	8	Gravity	2	0 - 1.6
CBC009	3,472,673	12,138,350	8	Gravity	1	0 - 2.0
CBC010	3,472,673	12,137,650	8	Gravity	3	0 - 2.0
CBC011	3,472,669	12,138,951	11	Gravity	1	0 - 2.0
CBC012	3,472,674	12,139,251	13	Gravity	1	0 - 2.0
CBC013	3,472,676	12,139,554	18	Gravity	1	0 - 2.0
CBC014	3,472,377	12,138,048	4	Gravity	1	0 - 2.0
CBC015	3,472,381	12,138,348	5	Gravity	1	0 - 1.5
CBC016	3,472,376	12,138,647	5	Gravity	1	0 - 2.0
CBC017	3,472,375	12,138,942	6	Gravity	1	0 - 2.0
CBC018	3,472,370	12,139,243	6	Gravity	1	0 - 2.0
CBC019	3,472,369	12,139,552	6	Gravity	1	0 - 2.0
CBC020	3,472,371	12,139,852	7	Gravity	1	0 - 2.0
CBC021	3,472,081	12,138,042	3	Gravity	1	0 - 1.9
CBC022	3,472,084	12,138,653	4	Gravity	1	0 - 2.0
CBC023	3,472,070	12,138,950	4	Gravity	1	0 - 2.0
CBC024	3,472,071	12,139,071	4	Gravity	1	0 - 2.0
CBC025	3,472,070	12,139,548	4	Gravity	1	0 - 1.3

Coordinates averaged for stations with 2 or more cores

TABLE 2-5. EPPINGER AND RUSSELL
SUMMARY OF STATION LOCATION AND CORE COMPOSITE INFORMATION

Station	Northing NAD 83 (ft)	Easting NAD 83 (ft)	Approximate Depth of Water (ft)	Coring Method	#Cores Composited	Depth of Core Composite or Core Length (ft)
Fine Grid						
ERF001	3,453,930	12,126,493	38	Gravity	-	0 - 1.9
ERF002	3,453,931	12,126,547	13	Gravity	-	0 - 2.0
ERF003	3,453,871	12,126,496	36	Gravity	-	0 - 1.5
ERF004	3,453,815	12,126,538	30	Gravity	-	0 - 1.6
ERF005	3,453,780	12,126,499	37	Gravity	-	0 - 2.1
ERF006	3,453,770	12,126,555	29	Gravity	-	0 - 2.5
ERF007	3,453,722	12,126,553	30	Gravity	-	0 - 2.25
ERF008	3,453,667	12,126,507	38	Gravity	-	0 - 1.9
ERF009	3,453,669	12,126,531	30	Gravity	-	0 - 2.0
ERF010	3,453,620	12,126,545	29	Gravity	-	0 - 2.4
ERF011	3,453,573	12,126,520	31	Gravity	2	0 - 2.0
ERF012	3,453,525	12,126,497	32	Gravity	-	0 - 2.25
ERF013	3,453,493	12,126,506	29	Gravity	-	0 - 1.6
ERF014	3,453,464	12,126,601	15	Gravity	-	0 - 1.9
ERF015	3,453,432	12,126,498	31	Gravity	-	0 - 2.75
ERF016	3,453,426	12,126,588	15	Gravity	-	0 - 1.5
ERF017	3,453,078	12,126,507	30	Gravity	-	0 - 2.25
ERF018	3,453,740	12,126,554	28	Gravity	-	0 - 2.2
ERF019	3,453,241	12,126,446	16	Gravity	-	0 - 2.2
ERF020	3,453,220	12,126,542	26	Gravity	-	0 - 2.1
ERF021	3,453,323	12,126,587	15	Gravity	-	0 - 1.6
ERF022	3,453,256	12,126,470	35	Gravity	-	0 - 2.3
ERF023	3,453,281	12,126,537	28	Gravity	-	0 - 1.4
ERF024	3,453,229	12,126,445	35	Gravity	-	0 - 2.25
ERF025	3,453,211	12,126,534	38	Gravity	-	0 - 2.2
Coarse Grid						
ERC001	3,452,957	12,126,396	40	Gravity	2	0 - 1.75
ERC002	3,452,870	12,126,613	8	Gravity	-	0 - 2.3
ERC003	3,452,638	12,126,290	39	Gravity	-	0 - 2.3
ERC004	3,452,562	12,126,591	10	Gravity	3	0 - 2.0
ERC005	3,453,944	12,126,474	38	Gravity	2	0 - 2.0
ERC006	3,454,125	12,126,608	20	Gravity	-	0 - 2.0
ERC007	3,454,554	12,126,699	27	Gravity	-	0 - 2.0
ERC008	3,454,803	12,126,819	26	Gravity	2	0 - 2.0
ERC009	3,454,613	12,126,874	4	Gravity	-	0 - 1.2

Coordinates averaged for stations with 2 or more cores

TABLE 2-6 GRID SPACING FOR TARGET STATION LOCATIONS

Location	Approximate Grid Spacing	Number of Stations
Scuffletown Creek	100 ft	100
	50 ft	81
Scotts Creek	300 ft	16
	100 ft	16
East of Campostella Bridge	300 ft	25
	100 ft	9
Eppinger & Russell	300 ft	9
	50 ft	25
Total		281

TABLE 2-7. SUMMARY OF FIELD DUPLICATE SAMPLES AND SAMPLES SUBMITTED TO USEPA ENVIRONMENTAL RESEARCH LAB-NARRAGANSETT (ERL-N)

Field Duplicates	Samples Submitted to EPA Narragansett
Scuffletown Creek	**Eppinger & Russell**
SFC010-01 FD	ERF011
SFC020-01 FD [a]	ERC001
SFC030-01 FD	ERC004
SFC040-01 FD	ERC005
SFC050-01 FD	ERC008
SFC057-01 FD	
SFC060-01 FD	**Scuffletown Creek**
SFC070-01 FD	SFC010-01
SFC080-01 FD	SFC020-01
SFC090-01 FD	SFC030-01
SFF020-01 FD [ab]	SFC040-01
SFF030-01 FD	SFC050-01
SFF040-01 FD	SFC057-01
SFF050-01 FD	SFC064-01
SFF060-01 FD	SFC070-01
	SFC073-01
Scotts Creek	SFC090-01
SCC002 FD [a]	SFF020-01
	SFF030-01
East of Campostella	SFF040-01
CBC010 FD	SFF050-01
CBF005 FD [ab]	SFF060-01
Eppinger & Russell	
ERC004 FD [a]	

a = organochlorine pesticide analysis
b = PCB congener and PCT aroclor analysis

3. ANALYTICAL TESTING AND DATA VALIDATION

3.1 ANALYTICAL TESTING OF BULK SEDIMENTS

Analytical testing of the sediment was conducted by EA Laboratories in Sparks, Maryland. Bulk sediments were tested for the following compounds using the most current EPA SW-846 guidelines: semivolatile organic compounds, PCB aroclors and congeners, PCT aroclors (5432 and 5460), organochlorine pesticides, PP metals, and TOC. Grain size determination was conducted in EA's Ecotoxicology Laboratory.

In addition to sediment samples, quality control (QC) samples were submitted to the laboratory for analysis. Field duplicate (FD) samples, field blanks, equipment rinsate blanks, and processing blanks were analyzed for the project. Extra sample volume was submitted to the laboratory for matrix spike (MS)/ matrix spike duplicate (MSD) analyses. A summary of analytical and QC samples submitted for analyses is provided in Table 3-1.

Concentrations of inorganic and organic compounds for the project were determined using the methods listed in Table 3-2 and are reported on a dry weight basis (mg/kg).

3.2 DETECTION LIMITS

The detection limit is a statistical concept that corresponds to the minimum concentration of an analyte above which the net analyte signal can be distinguished with a specified probability from the signal due to the noise inherent in the analytical system. The method detection limit (MDL) was developed by the EPA, and is defined as "the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero" (40 CFR 136, Appendix B). Detection limits applicable to this project are listed in Tables 3-3 for sediment samples and aqueous field blanks.

For this project, results were reported to the reporting limits listed in Table 3-3. The Reporting Limits (RLs) are the laboratory quantitation levels. These values represent the minimum concentrations to be reported for routine laboratory analyses in a variety of environmental matrices at the stated precision and accuracy of the method.

If an analyte was detected between the project RL and the MDL, the reporting limit was flagged with a "J" (estimated) in the analytical results.

In order to achieve a consistent reporting limit for sediment samples, which characteristically have moisture contents in excess of 20%, the sample weight taken for analysis was adjusted for the percent moisture in the sample, prior to analysis.

A substantial number of samples for the Elizabeth River Phase I Sediment Investigation required dilutions due to the high concentrations of detected compounds. The MDL increases proportionally to the dilution factor for a given sample.

3.3 LABORATORY QUALITY CONTROL SAMPLES

For each analytical method, the laboratory quality control samples were analyzed at the frequency consistent with EPA methodology and guidelines (Table 3-4). Acceptance criteria are specified in the methods and are listed in Appendix B of the QAPP (EA 1999).

3.3.1 Method Blanks

The method (reagent) blank is used to monitor laboratory contamination. This is usually a sample of laboratory reagent water processed through the same analytical procedure as the sample (i.e., digested, extracted, distilled). One method blank was analyzed at a frequency of one per every analytical preparation batch of twenty (20) or fewer samples.

3.3.2 Laboratory Control Sample

The Laboratory Control Sample is a fortified method blank consisting of reagent water or solid fortified with the analytes of interest for single-analyte methods and selected analytes for multi-analyte methods according to the appropriate analytical method. They were prepared and analyzed with each analytical batch, and analyte recoveries were used to monitor analytical accuracy and precision.

3.3.3 Matrix Spike/Matrix Spike Duplicate

A fortified sample (matrix spike) is an aliquot of a field sample which is fortified with the analyte(s) of interest and analyzed to monitor matrix effects associated with a particular sample. Samples to be spiked are chosen at random. The final spiked concentration of each analyte in the sample should be at least ten times the calculated MDL. A duplicate fortified sample (matrix spike duplicate) was performed for every batch of twenty (20) or fewer samples.

3.3.4 Surrogates

Surrogates are organic compounds that are similar to analytes of interest in chemical composition, extraction, and chromatography, but are not normally found in environmental samples. These compounds were spiked into blanks, standards, samples, and spiked samples prior to analysis for organic parameters. Generally, surrogates are not used for inorganic analyses. Percent recoveries were calculated for each surrogate. Surrogates were spiked into samples according to the requirements of the reference analytical method. Surrogate spike recoveries were evaluated by the limits in Appendix A of the QAPP (EA 1999), and were used to assess method performance and sample measurement bias. If sample dilution caused the surrogate concentration to fall below the quantitation limit, surrogate recoveries were not calculated.

3.4 ANALYTICAL DATA VALIDATION

Validation of the analytical data was conducted by Environmental Data Services, Inc. (EDS) located in Concord, New Hampshire. The data validation protocols were derived from the following EPA guidelines allowing for the quality control requirements specific to the methods used for this project:

- *Region III Modifications to the National Functional Guidelines for Organic Data Review* (USEPA, September 1994).
- *Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* (USEPA, April 1993).
- *Region III Innovative Approaches to Data Validation* (USEPA Region III, 1995).

Data was reported at a Level IV data validation. Level IV is equivalent to the M-3 Level of data validation for organic data and the IM-2 Level of data validation for inorganic data.

Data validation procedures were originally developed by the EPA for data generated using protocols of the U.S. EPA Contract Laboratory Program for sites regulated under CERCLA, and are specified in *Functional Guidelines for Evaluating Organic/Inorganic Analyses* (USEPA 1994a). The process is used to evaluate the technical usability of a data set as defined by project specific Data Quality Objectives.

For this project, the specified validation protocols did not accommodate the SW-846 methods. This could have resulted in the rejection of data that were actually valid. Upon approval by Norfolk District USACE, EA Laboratories submitted modified validation guidelines to EDS that were developed and used by EA Laboratories to validate SW-846 data. EA Laboratories worked with EDS prior to the submission of data to be sure that EDS understood the modified validation guidelines and procedures. The modified validation guidelines, procedures, and checklists are provided in the QAPP (EA 1999) and attached to this Data Report as Appendix B.

The data validation reports (DVR) for each Sample Delivery Group (SDG) are provided in Appendix D (Volume III of this data report). The DVRs include:

- An overview and summary of the DVR that includes findings by analyses type and a report content statement
- Glossary of qualifiers and terms used
- Copies of U.S. EPA Form Is and/or equivalents
- Copies of case narratives and chain-of-custody forms

- A report for each parameter group for the SDGs including an introduction, full sample IDs, and technical review comments for each required performance criterion with the actions taken

- Data limitations including data usability statements

3.5 DATA QUALITY OBJECTIVES

The data from the Elizabeth River Phase I Sediment Investigation will be used to describe the existing physical and chemical characteristics of the substrate and to identify potential contaminants of concern. The results will be used to plan future studies and to evaluate future remediation strategies and alternatives for each of the four designated areas.

The data results from the analytical testing were compared against two sets of marine sediment quality guidelines (SQG).

3.5.1 Effects-Range Low (ERL) and Effects-Range Median (ERM)

ERL and ERM are effects-based criteria derived from a combination of equilibrium-partitioning modeling, field studies, and laboratory bioassays (Long and Morgan 1990; Long *et al.* 1995). Chemical concentrations below the ERL value represent the minimal effects range (effects rarely observed). Concentrations that equal or exceed the ERL value and fall below the ERM value represent the possible-effects range (effects occasionally observed). Concentrations equivalent to or greater than the ERM represent the probable-effects range (effects frequently observed).

3.5.2 Threshold Effects Limit (TEL) and Probable Effects Limit (PEL)

PEL and TEL are effects-based criteria that have been applied to contaminated sediments in Florida and other areas of the sourtheastern United States (MacDonald 1994; MacDonald *et al.* 1996). TELs represent the concentration below which adverse biological effects rarely occur. PELs represent the concentration above which adverse biological effects frequently occur. Values that fall between the TEL and PEL represent the concentrations at which adverse biological effects occasionally occur.

The minimum SQG concentration (minimum DQO) was used for the screening comparisons with each compound. SQG values for ERL, ERM, TEL, and PEL are provided in Table 3-5.

TABLE 3-1. SUMMARY OF ANALYTICAL AND QC SAMPLES FOR THE ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION

Analytical Fraction	Semivolatile Organics	Organochlorine Pesticides/ PCB Aroclors	Metals	PCB Congeners	PCT Aroclors (5432 and 5460)	TOC	Grain Size
Field Samples							
Scuffletown Creek	256	69	256	27	27	256	256
Scotts Creek	31	6	31	3	3	31	31
Campostella Bridge	32	6	32	3	3	32	32
Eppinger and Russell	5	1	5	3	3	5	5
QC Samples							
Field Duplicates	19	4	19	2	2	19	20*
Field Blanks	26	5	26	4	4	26	0
Equipment Blanks	27	5	27	3	3	27	0
TOTAL	396	96	396	49	49	396	344

*Duplicate analysis conducted for grain size

TABLE 3-2. ANALYTICAL METHODS

Parameter	Method	Reference Method	EAL Method SOP	Matrix	Reference
SAMPLE PREPARATION					
Mercury	Atomic Absorption - Cold Vapor	7470A	EAL -M-7470/1-P	W	EPA, 1997
Mercury	Atomic Absorption - Cold Vapor	7471A	EAL- M-7470/1A-P	S	EPA, 1997
Semivolatile Organics Extraction	Continuous Extraction	3520C	EAL-M-3520C	W	EPA, 1997
Semivolatile Organics Extraction	Soxhlet Extraction	3540C	EAL-M-3540C	S	EPA, 1997
Total Metals Digestion	Nitric Acid - Hydrogen Peroxide	3050A	EAL-M-3050A	S	EPA, 1997
Total Metals Digestion (FAA/ICP)	Nitric Acid - Hydrochloric Acid	3010A	EAL-M-3010A	W	EPA, 1997
Total Metals Digestion (GFAA)	Nitric Acid	3020A	EAL-M-3020A	W	EPA, 1997
ORGANICS					
Acid Extractable Organics	Gas Chromatography/Mass Spectrometry	8270C	EAL -M-8270C	W,S	EPA, 1997
Base-Neutral Extractable Organics	Gas Chromatography/Mass Spectrometry	8270C	EAL -M-8270C	W,S	EPA, 1997
Chlorinated Pesticides	Gas Chromatography - ECD	8081A	EAL -M-8081A	W,S	EPA, 1997
PCB Congeners	Gas Chromatography - ECD	8082	EAL -M-8082	W,S	EPA, 1997
Total Organic Carbon	IR Spectrometry	9060	EAL -M-9060	W,S	EPA, 1997
METALS					
Antimony	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Arsenic	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Beryllium	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Cadmium	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Chromium, Total	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Copper	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Lead	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Mercury	Atomic Absorption - Cold Vapor, Autoclave Digestion Procedure	7470A	EAL-M-7470/1	W	EPA, 1997
Mercury	Atomic Absorption - Cold Vapor	7471A	EAL-M-7470/1	S	EPA, 1997
Nickel	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Selenium	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA 1997

TABLE 3-2. (CONTINUED)

Parameter	Method	Reference Method	EAL Method SOP	Matrix	Reference
Silver	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
Thallium	Atomic Emission - Furnace	7841	EAL-M-7000Series	W,S	EPA, 1997
Zinc	Atomic Emission - ICP	6010B	EAL -M-6010B	W,S	EPA, 1997
PHYSICAL PARAMETERS					
Particle Size	Hydrometer	D422	--	S	ASTM, 1995
Percent Moisture	Gravimetric - 103 - 105C	D2216	--	S	ASTM, 1995

Matrix Codes:

W - Rinsate and processing blanks

S - Sediments

References:

ASTM, 1995. American Society for Testing Materials. 1995. Annual Book of ASTM Standards, Volume 11.01. ASTM, Philadelphia, Pennsylvania.

EPA, 1997. United States Environmental Protection Agency. June 1997. Test Methods for Evaluating Solid Waste. Physical/Chemical Methods. EPA SW-846, 3rd edition, including UPDATE III. U.S. EPA, Washington, D.C.

TABLE 3-3. PROJECT REPORTING LIMITS AND METHOD DECTECTION LIMITS FOR SEDIMENT, RINSATE, AND PROCESSING BLANKS

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
SEMIVOLATILES (SW8270C)							
Phenol	108-95-2	ug/L	10	4	ug/kg	330	89
bis-(2-Chloroethyl)ether	111-44-4	ug/L	10	4	ug/kg	330	110
2-Chlorophenol	95-57-8	ug/L	10	3	ug/kg	330	110
1,3-Dichlorobenzene	541-73-1	ug/L	10	3	ug/kg	330	110
1,4-Dichlorobenzene	106-46-7	ug/L	10	3	ug/kg	330	99
1,2-Dichlorobenzene	95-50-1	ug/L	10	2	ug/kg	330	110
2-Methylphenol	95-48-7	ug/L	10	4	ug/kg	330	91
2,2'-oxybis (1-Chloropropane)	108-60-1	ug/L	10	4	ug/kg	330	230
4-Methylphenol	106-44-5	ug/L	10	4	ug/kg	330	100
N-Nitroso-di-n-propylamine	621-64-7	ug/L	10	4	ug/kg	330	99
Hexachloroethane	67-72-1	ug/L	10	3	ug/kg	330	110
Nitrobenzene	98-95-3	ug/L	10	4	ug/kg	330	100
Isophorone	78-59-1	ug/L	10	4	ug/kg	330	100
2-Nitrophenol	88-75-5	ug/L	10	3	ug/kg	330	100
2,4-Dimethylphenol	105-67-9	ug/L	10	3	ug/kg	330	92
bis(2-Chloroethoxy)methane	111-91-1	ug/L	10	4	ug/kg	330	100
2,4-Dichlorophenol	120-83-2	ug/L	10	3	ug/kg	330	82
1,2,4-Trichlorobenzene	120-82-1	ug/L	10	3	ug/kg	330	100
Naphthalene	91-20-3	ug/L	10	3	ug/kg	330	100

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
4-Chloroaniline	106-47-8	ug/L	10	5	ug/kg	330	85
Hexachlorobutadiene	87-68-3	ug/L	10	4	ug/kg	330	110
4-Chloro-3-methylphenol	59-50-7	ug/L	10	4	ug/kg	330	96
1-Methylnaphthalene (a)	90-12-0	ug/L	10	---	ug/kg	330	---
2-Methylnaphthalene	91-57-6	ug/L	10	3	ug/kg	330	110
Hexachlorocyclopentadiene	77-47-4	ug/L	10	2	ug/kg	330	95
2,4,6-Trichlorophenol	88-06-2	ug/L	10	3	ug/kg	330	92
2,4,5-Trichlorophenol	95-95-4	ug/L	25	3	ug/kg	830	99
2-Chloronaphthalene	91-58-7	ug/L	10	3	ug/kg	330	120
2-Nitroaniline	88-74-4	ug/L	25	5	ug/kg	830	96
Dimethylphthalate	131-11-3	ug/L	10	3	ug/kg	330	84
Acenaphthylene	208-96-8	ug/L	10	4	ug/kg	330	97
2,6-Dinitrotoluene	606-20-2	ug/L	25	4	ug/kg	830	110
3-Nitroaniline	99-09-2	ug/L	25	4	ug/kg	830	91
Acenaphthene	83-32-9	ug/L	10	3	ug/kg	330	140
2,4-Dinitrophenol	51-28-5	ug/L	10	3	ug/kg	330	190
4-Nitrophenol	100-02-7	ug/L	25	5	ug/kg	830	87
Dibenzofuran	132-64-9	ug/L	10	4	ug/kg	330	130
2,4-Dinitrotoluene	121-14-2	ug/L	10	4	ug/kg	330	110
Diethylphthalate	84-66-2	ug/L	10	3	ug/kg	330	88
4-Chlorophenyl-phenyl ether	7005-72-3	ug/L	10	4	ug/kg	330	130

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
Fluorene	86-73-7	ug/L	10	4	ug/kg	330	150
4-Nitroaniline	100-01-6	ug/L	25	4	ug/kg	830	77
4,6-Dinitro-2-methylphenol	534-52-1	ug/L	25	6	ug/kg	830	240
N-Nitrosodiphenylamine	86-30-6	ug/L	10	4	ug/kg	330	87
4-Bromophenyl-phenylether	101-55-3	ug/L	10	5	ug/kg	330	120
Hexachlorobenzene	118-74-1	ug/L	10	6	ug/kg	330	110
Pentachlorophenol	87-86-5	ug/L	25	5	ug/kg	330	140
Phenanthrene	85-01-8	ug/L	10	5	ug/kg	330	130
Anthracene	120-12-7	ug/L	10	4	ug/kg	330	120
Carbazole	86-74-8	ug/L	10	5	ug/kg	330	110
Di-n-butylphthalate	84-74-2	ug/L	10	4	ug/kg	330	150
Fluoranthene	206-44-0	ug/L	10	5	ug/kg	330	150
Pyrene	129-00-0	ug/L	10	4	ug/kg	330	76
Butylbenzylphthalate	85-68-7	ug/L	10	4	ug/kg	330	89
3,3'-Dichlorobenzidine	91-94-1	ug/L	10	4	ug/kg	330	71
Benzo(a)anthracene	56-55-3	ug/L	10	3	ug/kg	330	93
Chrysene	218-01-9	ug/L	10	3	ug/kg	330	110
bis(2-Ethylhexyl)phthalate	117-81-7	ug/L	10	7	ug/kg	330	94
Di-n-octylphthalate	117-84-0	ug/L	10	4	ug/kg	330	85
Benzo(b)fluoranthene	205-99-2	ug/L	10	4	ug/kg	330	92
Benzo(k)fluoranthene	207-08-9	ug/L	10	3	ug/kg	330	94

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
Benzo(a)pyrene	50-32-8	ug/L	10	4	ug/kg	330	93
Indeno(1,2,3-cd)-pyrene	193-39-5	ug/L	10	4	ug/kg	330	110
Dibenzo(a,h)-anthracene	53-70-3	ug/L	10	4	ug/kg	330	130
Benzo(g,h,i)perylene	191-24-2	ug/L	10	5	ug/kg	330	120
Benzo(e)pyrene (a)	192-97-2	ug/L	10	--	ug/kg	330	--
Perylene (a)	198-55-0	ug/L	10	--	ug/kg	330	--
PESTICIDES (SW8081A)							
alpha-BHC	319-84-6	ug/L	0.050	0.006	ug/kg	1.7	0.13
beta-BHC	319-85-7	ug/L	0.050	0.004	ug/kg	1.7	0.08
delta-BHC	319-86-8	ug/L	0.050	0.006	ug/kg	1.7	0.42
gamma-BHC (Lindane)	58-89-9	ug/L	0.050	0.004	ug/kg	1.7	0.11
Heptachlor	76-44-8	ug/L	0.050	0.03	ug/kg	1 7	0.11
Aldrin	309-00-2	ug/L	0.050	0.05	ug/kg	1 7	0.12
Heptachlor epoxide	111024-57-3	ug/L	0.050	0.01	ug/kg	1.7	0.11
Endosulfan I	959-98-8	ug/L	0.050	0.01	ug/kg	1.7	0.17
Dieldrin	60-57-1	ug/L	0.10	0.02	ug/kg	3.3	0.31
4,4'-DDE	75-55-9	ug/L	0.10	0.02	ug/kg	3.3	0.22
Endrin	72-20-8	ug/L	0.10	0.01	ug/kg	3.3	0.30
Endosulfan II	33213-65-9	ug/L	0.10	0.02	ug/kg	3.3	0.37
4,4'-DDD	72-54-8	ug/L	0.10	0.01	ug/kg	3.3	0.32
Endosulfan sulfate	1031-07-8	ug/L	0.10	0.02	ug/kg	3.3	0.35

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
4,4-DDT	50-29-3	ug/L	0.10	0.01	ug/kg	3.3	0.21
Methoxychlor	72-43-5	ug/L	0.50	0.05	ug/kg	17	1 1
Endrin ketone	53494-70-5	ug/L	0.10	0.02	ug/kg	3.3	1.2
Endrin aldehyde	7421-93-4	ug/L	0.10	0.03	ug/kg	3.3	1.3
alpha-Chlordane	5103-71-9	ug/L	0.050	0.02	ug/kg	1.7	0.10
gamma-Chlordane	5103-71-9	ug/L	0.050	0.01	ug/kg	1.7	0.15
Toxaphene	8001-35-2	ug/L	5.0	2.0	ug/kg	170	14
PCB and PCT Aroclors (SW8082)							
Aroclor 1016	12674-11-2	ug/L	1.0	0.6	ug/kg	33	9.3
Aroclor 1221	11104-28-2	ug/L	2.0	0.6	ug/kg	67	7 4
Aroclor 1232	11141-16-5	ug/L	1.0	0.8	ug/kg	33	10
Aroclor 1242	53469-21-9	ug/L	1.0	0.5	ug/kg	33	4.7
Aroclor 1248	12672-29-6	ug/L	1.0	0.5	ug/kg	33	8.4
Aroclor 1254	11097-69-1	ug/L	1.0	0.7	ug/kg	33	3.0
Aroclor 1260	11096-82-5	ug/L	1.0	0.1	ug/kg	33	8.0
Aroclor 5432	--	ug/L	5.0	1.0	ug/kg	170	18.0
Aroclor 5460	--	ug/L	5.0	1.0	ug/kg	170	28.0
PCB CONGENERS (SW8082) (b)							
2,4'-Dichlorobiphenyl (BZ# 8)	34883-43-7	ug/L	0.010	0.004	ug/kg	0.33	0.97
2,2',5-Trichlorobiphenyl (BZ# 18)	37680-65-2	ug/L	0.010	0.002	ug/kg	0.33	0.72
2,4,4'-Trichlorobiphenyl (BZ# 28)	7012-37-5	ug/L	0.010	0.002	ug/kg	0.33	0.84

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
2,2',3,5'-Tetrachlorobiphenyl (BZ# 44)	41464-39-5	ug/L	0.010	0.002	ug/kg	0.33	0.72
2,2',4,5'-Tetrachlorobiphenyl (BZ# 49)	41464-40-8	ug/L	0.010	0.002	ug/kg	0.33	0.97
2,2',5,5'-Tetrachlorobiphenyl (BZ# 52)	35693-99-3	ug/L	0.010	0.002	ug/kg	0.33	1.3
2,3',4,4'-Tetrachlorobiphenyl (BZ# 66)	32598-10-0	ug/L	0.010	0.002	ug/kg	0.33	0.89
3,3',4,4'-Tetrachlorobiphenyl (BZ# 77)	--	ug/L	0.010	0.003	ug/kg	0.33	1.8
2,2',3,4,5'-Pentachlorobiphenyl (BZ# 87)	38380-02-8	ug/L	0.010	0.003	ug/kg	0.33	0.82
2,2',4,5,5'-Pentachlorobiphenyl (BZ# 101)	37680-73-2	ug/L	0.010	0.002	ug/kg	0.33	0.83
2,3,3',4,4'-Pentachlorobiphenyl (BZ# 105)	32598-14-4	ug/L	0.010	0.002	ug/kg	0.33	0.86
2,3',4,4',5-Pentachlorobiphenyl (BZ# 118)	31508-00-6	ug/L	0.010	0.003	ug/kg	0.33	1.0
3,3',4,4',5-Pentachlorobiphenyl (BZ# 126)	--	ug/L	0.010	0.004	ug/kg	0.33	1.3
2,2',3,3',4,4'-Hexachlorobiphenyl (BZ# 128)	38380-07-3	ug/L	0.010	0.003	ug/kg	0.33	1.0
2,2',3,4,4',5'-Hexachlorobiphenyl (BZ# 138)	35065-28-2	ug/L	0.010	0.001	ug/kg	0.33	1.0
2,2',4,4',5,5'-Hexachlorobiphenyl (BZ# 153)	35065-27-1	ug/L	0.010	0.001	ug/kg	0.33	0.99
2,3,3',4,4',5-Hexachlorobiphenyl (BZ# 156)	--	ug/L	0.1	0.056	ug/kg	0.33	1.2
3,3',4,4',5,5'-Hexachlorobiphenyl (BZ# 169)	--	ug/L	0.1	0.020	ug/kg	0.33	1.6
2,2',3,3',4,4',5-Heptachlorobiphenyl (BZ# 170)	35065-30-6	ug/L	0.010	0.002	ug/kg	0.33	0.98
2,2',3,4,4',5,5'-Heptachlorobiphenyl (BZ# 180)	35065-29-3	ug/L	0.010	0.001	ug/kg	0.33	1.1
2,2',3,4,4',5',6-Heptachlorobiphenyl (BZ# 183)	52663-69-1	ug/L	0.010	0.002	ug/kg	0.33	0.63
2,2',3,4,4',6,6'-Heptachlorobiphenyl (BZ# 184)	74472-48-3	ug/L	0.010	0.001	ug/kg	0.33	0.79
2,2',3,4',5,5',6-Heptachlorobiphenyl (BZ# 187)	52663-68-0	ug/L	0.010	0.001	ug/kg	0.33	0.78
2,2',3,3',4,4',5,6-Octachlorobiphenyl (BZ# 195)	52663-78-2	ug/L	0.010	0.003	ug/kg	0.33	1.2

TABLE 3-3. (CONTINUED)

Target Compound	CAS Number	Rinsate and Process Blanks			Sediment		
		Units	RL	MDL	Units (dry weight)	RL	MDL
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (BZ# 206)	40186-72-9	ug/L	0.010	0.003	ug/kg	0.33	1.2
2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (BZ#209)	2051-24-3	ug/L	0.010	0.003	ug/kg	0.33	1.0
METALS (SW6010B, SW7470A, SW7471A)							
Antimony	7440-36-0	ug/L	200	60	mg/kg	6.0	0.10
Arsenic	7440-38-2	ug/L	10	1	mg/kg	10.0	0.2
Beryllium	7440-41-7	ug/L	5	1	mg/kg	0.50	0.10
Cadmium	7440-43-9	ug/L	20	3	mg/kg	0.50	0.07
Chromium	7440-47-3	ug/L	10	0.6	mg/kg	1.0	0.4
Copper	7440-50-8	ug/L	25	5	mg/kg	2.5	0.2
Lead	7439-92-1	ug/L	3	2	mg/kg	0.3	0.10
Mercury	7439-97-6	ug/L	0.2	0.1	mg/kg	0.1	0.10
Nickel	7440-02-0	ug/L	40	5	mg/kg	4.0	0.5
Selenium	7782-49-2	ug/L	10	2	mg/kg	0.5	0.20
Silver	7440-22-4	ug/L	10	2	mg/kg	1.0	0.1
Thallium	7440-28-0	ug/L	10	1	mg/kg	1.0	0.1
Zinc	7440-66-6	ug/L	20	10	mg/kg	2.0	1.2
Total Organic Carbon (SW9060)	--	mg/L	1.0	0.2	mg/kg	6000	547

TABLE 3-4 TYPE AND FREQUENCY OF LABORATORY QUALITY CONTROL SAMPLES

Sediment Samples	
Method Blank (MB)	1 per analytical batch
Laboratory Control Sample (LCS)	1 per analytical batch
Matrix Spike (MS)	1 per analytical batch
Matrix Spike Duplicate (MSD)	1 per analytical batch
Surrogates	Spiked into field and QC samples
Rinsate and Process Blanks	
Method Blank	1 per analytical batch
Laboratory Control Sample	1 per analytical batch

TABLE 3-5. MARINE SEDIMENT QUALITY GUIDELINES

Chemical Name	Units	Effects Range Low (ERL)	Effects Range Median (ERM)	Threshold Effects Limit (TEL)	Probable Effects Limit (PEL)
2-METHYLNAPHTHALENE	mg/kg	0.07	0.67	**0.02021**	0.20128
4,4'-DDT	mg/kg	**0.001**	0.007	0.00119	0.00477
ACENAPHTHENE	mg/kg	0.016	0.5	**0.00671**	0.0889
ACENAPHTHYLENE	mg/kg	0.044	0.64	**0.00587**	0.12787
ANTHRACENE	mg/kg	0.0853	1 1	**0.04685**	0.245
ARSENIC	mg/kg	8.2	70	**7.24**	41.6
BENZO(A)PYRENE	mg/kg	0.43	1.6	**0.08881**	0.76322
BENZO[A]ANTHRACENE	mg/kg	0.261	1.6	**0.07483**	0.69253
BIS(2-ETHYLHEXYL) PHTHALATE (DIETHYLHEXYL PHTHALATE)	mg/kg			**0.18216**	2.64651
CADMIUM	mg/kg	1.2	9.6	**0.676**	4.21
CHLORDANE (DQO for chlordane isomers)	mg/kg	**0.0005**	0.006	0.00226	0.00479
CHROMIUM	mg/kg	81	370	**52.3**	160.4
CHRYSENE	mg/kg	0.384	2.8	**0.10777**	0.84598
COPPER	mg/kg	34	270	**18.7**	108.2
DIBENZ(A,H)ANTHRACENE	mg/kg	0.0634	0.26	**0.00622**	0.13461
DICHLORODIPHENYLDICHLOROETHANE	mg/kg	0.002	0.02	**0.00122**	0.00781
DICHLORODIPHENYLDICHLOROETHYLENE	mg/kg	0.0022	0.027	**0.00207**	0.37417
DIELDRIN	mg/kg	**0.00002**	0.008	0.000715	0.0043
FLUORANTHENE	mg/kg	0.6	5.1	**0.11282**	1 49354
FLUORENE	mg/kg	**0.019**	0.54	0.02117	0.14435
LEAD	mg/kg	46.7	218	**30.24**	112.18
LINDANE	mg/kg			**0.00032**	0.00099
MERCURY	mg/kg	0.15	0.71	**0.13**	0.696
NAPHTHALENE	mg/kg	0.16	2.1	**0.03457**	0.39064
NICKEL	mg/kg	20.9	51.6	**15.9**	42.8
PCBs, (DQO for PCB aroclors)	mg/kg	0.0227	0.18	**0.02155**	0.18879
PHENANTHRENE	mg/kg	0.24	1.5	**0.08668**	0.54353
PYRENE	mg/kg	0.665	2.6	**0.15266**	1.3976
SILVER	mg/kg	1	3.7	**0.73**	1 7
ZINC	mg/kg	150	410	**124**	271

Bolded values represent the minimum DQO

Notes:
EA Laboratories does not have an MDL value for 1-methylnapthalene, benz(e)pyrene, or perylene, because the lab does not routinely analyze for these compounds by method SW 8270C. Because the isomers have similar responses, the RLs for these compounds were derived from RLs for 2-methylnapthalene (RL used for 1-methylnapthalene) and for benzo(a)pyrene (RL for both benz(e)pyrene and perylene). The low-calibration standard was substituted in place of the MDL for these three compounds.

Individual PCB aroclors were compared against the SQG value for total PBCs.

Chlordane isomers were compared against the SQG value for total chlordane.

TABLE 4-1 ORGANIC DATA QUALIFIERS

Qualifiers other than those listed below may be required to properly define the results. If used, they are given an alphabetic designation not already specified in this table or in a project/program document such as a Quality Assurance Project Plan or a contract Statement of Work. Each additional qualifier is fully described in the Analytical Narrative section of the laboratory report.

U Indicates a target compound was analyzed for but not detected. The sample Reporting Limit (RL) is corrected for dilution and, if a soil sample, for percent moisture, if reported on a dry weight basis.

J Indicates an estimated value. This qualifier is used under the following circumstances:

1) when estimating a concentration for tentatively identified compounds (TICs) in GC/MS analyses, where a 1:1 response is assumed,
2) when the mass spectral and retention time data indicate the presence of a compound that meets the volatile and semivolatile GC/MS identification criteria, and the result is less than the RL but greater than the method detection limit (MDL).

B This qualifier is used when the analyte is found in the associated method blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action. For GC/MS analyses, this qualifier is used for a TIC, as well as, for a positively identified target compound.

E This qualifier identifies compounds whose concentrations exceed the calibration range of the instrument for that specific analysis.

D When applied, this qualifier identifies all compound concentrations reported from a secondary dilution analysis.

A This qualifier indicates that a TIC is a suspected aldol-condensation product.

N Indicates presumptive evidence of a compound. This qualifier is only used for GC/MS TICs, where the identification is based on a mass spectral library search. For generic characterization of a TIC, such as chlorinated hydrocarbon, the N qualifier is not used.

P When applied, this qualifier indicates a reported value from a GC analysis when there is greater than 25% difference for detected concentrations between the two GC columns.

TABLE 4-2 INORGANIC DATA QUALIFIERS

C *(Concentration) qualifiers:*

B	Reported value is less than the project-specified Reporting Limit (RL), but greater than the method-specified Instrument Detection Limit (IDL) or Method Detection Limit (MDL).
U	Analyte analyzed for but not detected (concentration is less than the method-specified Instrument Detection Limit (IDL) or Method Detection Limit (MDL).

Q *(Quality control) qualifiers:*

E	Reported value is estimated because of presence of interference.
M	Duplicate injection precision not met.
N	Spiked sample recovery is not within control limits.
S	Reported value is determined by the method of standard additions (MSA).
W	Postdigestion spike for furnace Atomic Absorption Spectrophotometric (AAS) AAS analysis is out of control limits (85-115%) and sample absorbance is less than 50% of spike absorbance.
*	Duplicate analyses is not within control limits.
+	Correlation coefficient for MSA is less than 0.995.

M *(Method) qualifiers:*

P	Inductively Coupled Plasma (ICP)
A	Flame AAS
F	Furnace AAS
CV	Cold Vapor AAS
AV	Automated Cold Vapor AAS
AS	Semiautomated Spectrophotometric
C	Manual Spectrophotometric
T	Titrimetric
NR	Analyte is not required to be determined.

Elizabeth River Environmental Restoration Feasibility Report
APPENDIX E - Attachment C – Phase 1 Sediment Investigations
Synopsis of Detected Compounds and Sediment Quality Criteria Exceedences

ANALYTE NAME	Sediment Quality Criteria	LOCATION							
		Scuffletown Creek		Scotts Creek		Eppinger & Russell		Campostella Bridge	
	TEL or ERL mg/kg	No. of Exceed-ences	Max. Result mg/kg	No. of Exceed-ences	Max. Result mg/kg	No. of Exceed-ences	Max. Result mg/kg	No. of Exceed-ences	Max. Result mg/kg
ORGANICS*:									
2-Methylnaphthalene	.02021	271	3.4	32	2.6	6	34	34	0.34
Acenaphthene	.00671	271	5.3	32	2.4	6	71	34	1.1
Acenaphthylene	.00587	271	3.4	32	0.58	6	17	34	0.34
Anthracene	.04685	271	13.0	32	5.7	6	71	34	0.72
Benz (a)anthracene	.07483	270	6.7	29	10	6	38	34	0.82
Benzo (a)pyrene	.08881	265	9.8	29	8.8	6	28	33	0.71
Bis(2-ethylhexyl)phthalate	.1821	59	3.4	22	2.3	5	17	4	0.75
Dibenz(a,h)anthracene	.006	271	3.4	32	1.5	6	17	34	0.34
Fluoranthene	.1128	259	18.0	32	17	6	87	29	2.6
Fluorene	.019	271	4.0	32	4.4	6	54	34	0.99
Naphthalene	.0345	271	3.4	32	7	6	220	34	0.43
Phenanthrene	.0866	259	11.0	30	27	6	220	34	3.6
Pyrene	.152	192	23.0	28	30	6	65	13	3.1
METALS*:									
Arsenic	7.24	207	38.3	29	15.8	5	14.6	26	16.2
Chromium	52.3	9	61	5	261	0	48.3	0	47.1
Copper	18.7	177	400	31	199	5	108	16	147
Lead	30.24	177	1210	30	633	6	251	13	171
Zinc	124	139	832.	27	901	5	246	13	457

*not complete list of tested analytes

TABLE 4-3A. SCUFFLETOWN CREEK SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scuffletown Creek (0-1ft and 1-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
SFC001-01	X		X	X			X			990454
SFC001-12	X		X	X			X			990454
SFC003-01	X		X	X			X			990287
SFC003-12	X		X	X			X			990287
SFC004-01	X		X	X			X			990287
SFC004-12	X		X	X			X			990287
SFC005-01	X	X	X	X	X	X	X			990287
SFC005-12	X	X	X	X			X			990287
SFC006-01	X		X	X			X			990350
SFC007-01	X		X	X			X			990337
SFC007-12	X		X	X			X			990337
SFC008-01	X		X	X			X			990350
SFC008-12	X		X	X			X			990350
SFC009-01	X		X	X			X			990287
SFC009-12	X		X	X			X			990287
SFC010-01	X	X	X	X	X	X	X	X	X	990287
SFC010-01FD	X		X	X						990287
SFC010-12	X	X	X	X			X			990287
SFC011-01	X		X	X			X			990265
SFC011-12	X		X	X			X			990265
SFC012-01	X		X	X			X			990287
SFC012-12	X		X	X			X			990287
SFC013-01	X		X	X			X			990287
SFC013-12	X		X	X			X			990287
SFC014-01	X		X	X			X			990365
SFC014-12	X		X	X			X			990365
SFC015-01	X		X	X			X			990350
SFC016-01	X		X	X			X			990337
SFC017-01	X		X	X			X			990287
SFC017-12	X		X	X			X			990287
SFC018-01	X		X	X			X			990287
SFC018-12	X		X	X			X			990287
SFC019-01	X		X	X			X			990287
SFC019-12	X		X	X			X			990293
SFC020-01	X	X	X	X	X	X	X	X	X	990337
SFC020-01FD	X		X	X						990337
SFC020-12	X	X	X	X			X			990337
SFC021-01	X	X	X	X	X	X	X			990350
SFC021-12	X	X	X	X			X			990350
SFC022-01	X		X	X			X			990293
SFC022-12	X		X	X			X			990293
SFC023-01	X		X	X			X			990293
SFC023-12	X		X	X			X			990293
SFC024-01	X		X	X			X			990293
SFC024-12	X		X	X			X			990293
SFC025-01	X	X	X	X	X	X	X			990293
SFC025-12	X	X	X	X			X			990293
SFC026-01	X		X	X			X			990293
SFC026-12	X		X	X			X			990293
SFC027-01	X		X	X			X			990337
SFC027-12	X		X	X			X			990337
SFC028-01	X		X	X			X			990350
SFC028-12	X		X	X			X			990350
SFC029-01	X		X	X			X			990350
SFC029-12	X		X	X			X			990350

TABLE 4-3A. SCUFFLETOWN CREEK. SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scuffletown Creek (0-1ft and 1-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
SFC030-01	X	X	X	X	X	X	X	X	X	990344
SFC030-01FD	X		X	X						990344
SFC030-12	X	X	X	X			X			990344
SFC031-01	X		X	X			X			990337
SFC032-01	X		X	X			X			990337
SFC032-12	X		X	X			X			990337
SFC033-01	X	X	X	X			X			990350
SFC033-12	X	X	X	X			X			990350
SFC034-01	X		X	X			X			990350
SFC035-01	X		X	X			X			990350
SFC036-01	X		X	X			X			990350
SFC037-01	X		X	X			X			990350
SFC038-01	X		X	X			X			990337
SFC039-01	X		X	X			X			990337
SFC039-12	X		X	X			X			990337
SFC040-01	X	X	X	X	X	X	X	X	X	990350
SFC040-01FD	X		X	X						990350
SFC040-12	X	X	X	X			X			990350
SFC041-01	X		X	X			X			990337
SFC041-12	X		X	X			X			990337
SFC042-01	X		X	X			X			990337
SFC042-12	X		X	X			X			990337
SFC043-01	X		X	X			X			990337
SFC043-12	X		X	X			X			990337
SFC044-01	X		X	X			X			990344
SFC044-12	X		X	X			X			990344
SFC045-01	X	X	X	X	X	X	X			990344
SFC045-12	X	X	X	X			X			990344
SFC046-01	X		X	X			X			990344
SFC046-12	X		X	X			X			990344
SFC047-01	X		X	X			X			990420
SFC047-12	X		X	X			X			990420
SFC048-01	X		X	X			X			990344
SFC048-12	X		X	X			X			990344
SFC049-01	X		X	X			X			990344
SFC049-12	X		X	X			X			990344
SFC050-01	X	X	X	X	X	X	X	X	X	990361
SFC050-01FD	X		X	X						990361
SFC050-12	X	X	X	X			X			990361
SFC054-01	X		X	X			X			990420
SFC054-12	X		X	X			X			990420
SFC057-01	X	X	X	X	X	X	X	X	X	990410
SFC057-01FD	X		X	X						990410
SFC057-12	X	X	X	X			X			990410
SFC058-01	X		X	X			X			990420
SFC058-12	X		X	X			X			990420
SFC059-01	X	X	X	X			X			990420
SFC059-12	X	X	X	X			X			990420
SFC060-01	X		X	X			X	X		990420
SFC060-01FD	X		X	X						990420
SFC061-01	X		X	X			X			990420
SFC061-12	X		X	X			X			990420
SFC062-01	X		X	X			X			990265
SFC062-12	X		X	X			X			990265
SFC063-01	X		X	X			X			990365

TABLE 4-3A. SCUFFLETOWN CREEK SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scuffletown Creek (0-1ft and 1-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
SFC063-12	X		X	X			X			990365
SFC064-01	X	X	X	X			X		X	990484
SFC064-12	X		X	X			X			990484
SFC065-01	X	X	X	X	X	X	X			990484
SFC065-12	X	X	X	X			X			990484
SFC066-01	X		X	X			X			990387
SFC066-12	X		X	X			X			990387
SFC067-01	X		X	X			X			990382
SFC067-12	X		X	X			X			990382
SFC068-01	X		X	X			X			990387
SFC068-12	X		X	X			X			990387
SFC069-01	X		X	X			X			990387
SFC069-12	X		X	X			X			990387
SFC070-01	X	X	X	X	X	X	X	X	X	990382
SFC070-01FD	X		X	X						990382
SFC070-12	X		X	X			X			990382
SFC071-01	X		X	X			X			990365
SFC071-12	X		X	X			X			990365
SFC072-01	X		X	X			X			990484
SFC072-12	X		X	X			X			990484
SFC073-01	X	X	X	X	X	X	X		X	990484
SFC073-12	X	X	X	X			X			990484
SFC074-01	X		X	X			X			990454
SFC075-01	X		X	X			X			990454
SFC076-01	X		X	X			X			990265
SFC076-12	X		X	X			X			990265
SFC077-01	X	X	X	X			X			990454
SFC077-12	X	X	X	X			X			990454
SFC078-01	X		X	X			X			990265
SFC078-12	X		X	X			X			990265
SFC079-01	X		X	X			X			990265
SFC079-12	X		X	X			X			990265
SFC080-01	X	X	X	X	X	X	X	X		990365
SFC080-01FD	X		X	X						990365
SFC080-12	X	X	X	X			X			990365
SFC081-01	X		X	X			X			990344
SFC081-12	X		X	X			X			990344
SFC082-01	X		X	X			X			990344
SFC082-12	X		X	X			X			990344
SFC083-01	X		X	X			X			990454
SFC084-01	X		X	X			X			990454
SFC084-12	X		X	X			X			990454
SFC085-01	X	X	X	X	X	X	X			990420
SFC085-12	X	X	X	X			X			990420
SFC086-01	X		X	X			X			990365
SFC086-12	X		X	X			X			990365
SFC087-01	X		X	X			X			990365
SFC087-12	X		X	X			X			990365
SFC088-01	X		X	X			X			990484
SFC088-12	X		X	X			X			990484
SFC089-01	X		X	X			X			990484
SFC089-12	X		X	X			X			990484
SFC090-01	X	X	X	X	X	X	X	X	X	990454
SFC090-01FD	X		X	X						990454
SFC091-01	X		X	X			X			990454

TABLE 4-3A. SCUFFLETOWN CREEK: SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scuffletown Creek (0-1ft and 1-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
SFC093-01	X		X	X			X			990454
SFC093-12	X						X			990454
SFC094-01	X	X	X	X			X			990454
SFC094-12	X	X	X	X			X			990454
SFC095-01	X	X	X	X			X			990344
SFC095-12	X	X	X	X			X			990344
SFC096-01	X		X	X			X			990344
SFC096-12	X		X	X			X			990350
SFF001-01	X		X	X			X			990449
SFF002-01	X		X	X			X			990387
SFF003-01	X		X	X			X			990382
SFF004-01	X		X	X			X			990382
SFF005-01	X	X	X	X			X			990387
SFF005-12	X	X	X	X			X			990387
SFF006-01	X		X	X			X			990382
SFF007-01	X		X	X			X			990382
SFF008-01	X		X	X			X			990382
SFF009-01	X		X	X			X			990382
SFF010-01	X		X	X			X			990387
SFF011-01	X		X	X			X			990382
SFF012-01	X		X	X			X			990382
SFF013-01	X		X	X			X			990382
SFF014-01	X		X	X			X			990387
SFF015-01	X		X	X			X			990382
SFF016-01	X		X	X			X			990387
SFF016-12	X		X	X			X			990387
SFF017-01	X		X	X			X			990382
SFF018-01	X	X	X	X			X			990382
SFF018-12	X	X	X	X			X			990382
SFF019-01	X		X	X			X			990387
SFF019-12	X		X	X			X			990387
SFF020-01	X	X	X	X	X	X	X	X	X	990387
SFF020-01FD	X	X	X	X	X	X				990387
SFF020-12	X	X	X	X			X			990387
SFF021-01	X		X	X			X			990350
SFF022-01	X		X	X			X			990361
SFF024-01	X		X	X			X			990361
SFF025-01	X		X	X			X			990365
SFF027-01	X		X	X			X			990365
SFF028-01	X	X	X	X	X	X	X			990449
SFF028-12	X	X	X	X			X			990449
SFF029-01	X		X	X			X			990361
SFF029-12	X		X	X			X			990361
SFF030-01	X	X	X	X			X	X	X	990361
SFF030-01FD	X		X	X						990361
SFF030-12	X	X	X	X			X			990361
SFF031-01	X		X	X			X			990361
SFF032-01	X		X	X			X			990361
SFF032-12	X		X	X			X			990361
SFF033-01	X		X	X			X			990361
SFF033-12	X		X	X			X			990361
SFF034-01	X		X	X			X			990361
SFF034-12	X		X	X			X			990361
SFF035-01	X	X	X	X	X	X	X			990382
SFF035-12	X	X	X	X			X			990382

TABLE 4-3A SCUFFLETOWN CREEK. SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scuffletown Creek (0-1ft and 1-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
SFF036-01	X		X	X			X			990361
SFF036-12	X		X	X			X			990361
SFF037-01	X	X	X	X	X	X	X			990382
SFF037-12	X	X	X	X			X			990382
SFF038-01	X		X	X			X			990361
SFF038-12	X		X	X			X			990361
SFF039-01	X		X	X			X			990361
SFF039-12	X		X	X			X			990361
SFF040-01	X	X	X	X	X	X	X	X	X	990365
SFF040-01FD	X		X	X						990365
SFF040-12	X	X	X	X			X			990365
SFF041-01	X		X	X			X			990361
SFF042-01	X		X	X			X			990361
SFF042-12	X		X	X			X			990361
SFF043-01	X		X	X			X			990387
SFF043-12	X		X	X			X			990387
SFF044-01	X		X	X			X			990449
SFF044-12	X		X	X			X			990449
SFF045-01	X	X	X	X	X	X	X			990449
SFF045-12	X	X	X	X			X			990449
SFF046-01	X		X	X			X			990449
SFF047-01	X		X	X			X			990410
SFF047-12	X		X	X			X			990410
SFF048-01	X		X	X			X			990410
SFF048-12	X		X	X			X			990410
SFF049-01	X		X	X			X			990449
SFF049-12	X		X	X			X			990449
SFF050-01	X	X	X	X	X	X	X	X	X	990375
SFF050-01FD	X		X	X						990375
SFF050-12	X	X	X	X			X			990375
SFF051-01	X	X	X	X	X	X	X			990375
SFF051-12	X	X	X	X			X			990375
SFF052-01	X		X	X			X			990420
SFF052-12	X		X	X			X			990420
SFF053-01	X		X	X			X			990420
SFF053-12	X		X	X			X			990420
SFF054-01	X	X	X	X	X	X	X			990375
SFF054-12	X	X	X	X			X			990375
SFF055-01	X	X	X	X	X	X	X			990375
SFF055-12	X	X	X	X			X			990375
SFF056-01	X		X	X			X			990420
SFF056-12	X		X	X			X			990420
SFF057-01	X		X	X			X			990420
SFF057-12	X		X	X			X			990420
SFF058-01	X		X	X			X			990420
SFF059-01	X		X	X			X			990401
SFF059-12	X		X	X			X			990401
SFF060-01	X	X	X	X	X	X	X	X	X	990375
SFF060-01FD	X		X	X						990375
SFF060-12	X	X	X	X			X			990375
SFF062-01	X		X	X			X			990375

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFC001-01	59%	1%	10%	1%	29%	60.2%
SFC001-12	68%	2%	1%	0%	29%	62.3%
SFC003-01	52%	1%	8%	1%	38%	59.4%
SFC003-12	47%	0%	3%	0%	50%	55.5%
SFC004-01	40%	1%	16%	1%	42%	50.2%
SFC004-12	51%	0%	6%	0%	43%	50.5%
SFC005-01	26%	1%	30%	1%	42%	52.5%
SFC005-12	48%	0%	8%	1%	43%	51.7%
SFC006-01	22%	1%	54%	2%	21%	42.4%
SFC007-01	33%	0%	36%	3%	28%	55%
SFC007-12	37%	0%	32%	4%	27%	52.3%
SFC008-01	53%	2%	15%	1%	29%	59.4%
SFC008-12	57%	0%	11%	1%	31%	56.9%
SFC009-01	46%	0%	5%	0%	49%	56.5%
SFC009-12	51%	0%	2%	0%	47%	59.8%
SFC010-01	37%	0%	23%	2%	38%	55.3%
SFC010-01 (duplicate)	40%	1%	21%	1%	37%	56.9%
SFC010-12	54%	0%	2%	1%	43%	60.5%
SFC011-01	42%	0%	13%	1%	44%	59.8%
SFC011-12	51%	0%	4%	1%	44%	58.8%
SFC012-01	36%	0%	21%	2%	41%	55.5%
SFC012-12	47%	0%	3%	1%	49%	55.5%
SFC013-01	34%	0%	14%	2%	50%	53.4%
SFC013-12	57%	0%	2%	1%	40%	50.7%
SFC014-01	45%	0%	7%	1%	47%	55.7%
SFC014-12	43%	0%	14%	1%	42%	51%
SFC015-01	32%	1%	40%	2%	25%	38.8%
SFC016-01	12%	1%	70%	4%	13%	30.9%
SFC017-01	56%	1%	12%	1%	30%	60.6%
SFC017-12	49%	1%	2%	1%	47%	62.7%
SFC018-01	54%	0%	7%	1%	38%	53.4%
SFC018-12	54%	0%	9%	2%	35%	49.9%
SFC019-01	49%	0%	12%	2%	37%	50.9%
SFC019-12	54%	1%	7%	1%	37%	48.4%
SFC020-01	33%	1%	25%	2%	39%	52.6%
SFC020-01 (duplicate)	31%	1%	29%	2%	37%	52.6%
SFC020-12	51%	0%	8%	1%	40%	52.6%
SFC021-01	36%	1%	21%	1%	41%	49.2%
SFC021-12	39%	0%	12%	1%	48%	50%
SFC022-01	32%	0%	26%	2%	40%	48.9%
SFC022-12	45%	0%	17%	1%	37%	50.9%
SFC023-01	42%	0%	27%	2%	29%	59.4%
SFC023-12	34%	1%	40%	2%	23%	44.9%
SFC024-01	22%	0%	58%	3%	17%	41.8%
SFC024-12	46%	0%	23%	1%	30%	51.9%
SFC025-01	45%	1%	31%	1%	22%	55.4%
SFC025-12	48%	0%	21%	1%	30%	55.4%

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFC026-01	52%	0%	14%	2%	32%	56.4%
SFC026-12	66%	0%	1%	1%	32%	55.9%
SFC027-01	34%	0%	35%	2%	29%	48.4%
SFC027-12	46%	0%	14%	2%	38%	50.3%
SFC028-01	18%	2%	56%	3%	21%	31.3%
SFC028-12	36%	1%	29%	3%	31%	46.2%
SFC029-01	22%	1%	34%	2%	41%	43%
SFC029-12	38%	0%	23%	2%	37%	43.2%
SFC030-01	29%	1%	30%	2%	38%	45.4%
SFC030-01 (duplicate)	28%	1%	33%	1%	37%	45.4%
SFC030-12	44%	0%	17%	2%	37%	49.7%
SFC031-01	36%	1%	16%	1%	46%	48.3%
SFC032-01	42%	0%	31%	1%	26%	52.5%
SFC032-12	61%	0%	2%	0%	37%	59.7%
SFC033-01	43%	1%	20%	1%	35%	50.8%
SFC033-12	55%	0%	6%	1%	38%	51.8%
SFC034-01	25%	1%	53%	3%	18%	44.7%
SFC035-01	29%	1%	39%	3%	28%	40.2%
SFC036-01	13%	0%	67%	5%	15%	26.5%
SFC037-01	36%	0%	36%	2%	26%	48.5%
SFC038-01	53%	1%	9%	1%	36%	55.9%
SFC039-01	39%	1%	31%	1%	28%	53.6%
SFC039-12	53%	0%	4%	1%	42%	53%
SFC040-01	40%	0%	21%	2%	37%	52.1%
SFC040-01 (duplicate)	42%	1%	20%	1%	36%	53%
SFC040-12	53%	0%	4%	1%	42%	53.3%
SFC041-01	35%	1%	23%	1%	40%	48.9%
SFC041-12	49%	0%	6%	1%	44%	51.8%
SFC042-01	64%	0%	3%	1%	32%	57.3%
SFC042-12	61%	0%	4%	1%	34%	56.9%
SFC043-01	36%	1%	30%	1%	32%	51.5%
SFC043-12	53%	0%	4%	1%	42%	51.8%
SFC044-01	61%	0%	2%	1%	36%	54.6%
SFC044-12	63%	0%	3%	0%	34%	52.6%
SFC045-01	56%	1%	5%	1%	37%	55.2%
SFC045-12	59%	4%	8%	1%	28%	54.4%
SFC046-01	27%	1%	53%	2%	17%	46.8%
SFC046-12	35%	0%	7%	1%	57%	52.5%
SFC047-01	60%	0%	7%	1%	32%	53%
SFC047-12	61%	0%	4%	0%	35%	50%
SFC048-01	53%	0%	5%	1%	41%	51%
SFC048-12	53%	0%	4%	1%	42%	49.2%
SFC049-01	35%	0%	6%	1%	58%	70.5%
SFC049-12	41%	0%	9%	1%	49%	64%
SFC050-01	32%	1%	38%	2%	27%	58.2%
SFC050-01 (duplicate)	33%	0%	39%	3%	25%	58.2%
SFC050-12	49%	1%	15%	2%	33%	60.8%

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFC054-01	37%	2%	14%	2%	45%	58.5%
SFC054-12	44%	0%	7%	1%	48%	49.5%
SFC057-01	47%	0%	6%	1%	46%	65.7%
SFC057-01 (duplicate)	47%	0%	7%	1%	45%	65.7%
SFC057-12	51%	0%	3%	1%	45%	55.8%
SFC058-01	38%	0%	6%	1%	55%	63.6%
SFC058-12	55%	0%	2%	1%	42%	60%
SFC059-01	29%	1%	34%	2%	34%	51%
SFC059-12	52%	0%	2%	1%	45%	58.7%
SFC060-01	8%	1%	72%	3%	16%	30%
SFC060-01 (duplicate)	9%	1%	73%	3%	14%	55.3%
SFC061-01	12%	1%	63%	5%	19%	34%
SFC061-12	56%	1%	3%	1%	39%	55.7%
SFC062-01	37%	1%	15%	1%	46%	58.7%
SFC062-12	51%	1%	2%	1%	45%	51.2%
SFC063-01	34%	1%	14%	4%	47%	60.2%
SFC063-12	46%	0%	3%	2%	49%	51%
SFC064-01	38%	0%	4%	1%	57%	64.4%
SFC064-12	51%	0%	6%	1%	42%	53.5%
SFC065-01	42%	0%	7%	1%	50%	63.9%
SFC065-12	53%	0%	2%	1%	44%	57.1%
SFC066-01	46%	0%	9%	2%	43%	55.1%
SFC066-12	50%	0%	6%	1%	43%	53.9%
SFC067-01	43%	1%	12%	1%	43%	58.2%
SFC067-12	48%	0%	4%	1%	47%	51.4%
SFC068-01	41%	0%	8%	2%	49%	60.9%
SFC068-12	52%	0%	4%	1%	43%	53.4%
SFC069-01	43%	1%	7%	1%	48%	57.5%
SFC069-12	52%	0%	3%	1%	44%	54.7%
SFC070-01	42%	0%	7%	1%	50%	58.9%
SFC070-01 (duplicate)	42%	0%	7%	1%	50%	58.9%
SFC070-12	49%	0%	0%	0%	51%	51.9%
SFC071-01	47%	0%	4%	1%	48%	62.5%
SFC071-12	49%	0%	2%	1%	48%	51.2%
SFC072-01	39%	0%	3%	1%	57%	62.4%
SFC072-12	53%	0%	2%	1%	44%	56.3%
SFC073-01	38%	0%	6%	1%	55%	65.2%
SFC073-12	55%	0%	2%	1%	42%	57.1%
SFC074-01	45%	0%	8%	1%	46%	65.8%
SFC075-01	51%	0%	6%	1%	42%	60.7%
SFC076-01	34%	1%	7%	1%	57%	65.4%
SFC076-12	50%	0%	2%	1%	47%	69.1%
SFC077-01	32%	4%	26%	7%	31%	60.4%
SFC077-12	56%	0%	1%	1%	42%	63%
SFC078-01	43%	0%	5%	2%	50%	67.5%
SFC078-12	52%	0%	2%	1%	45%	67%
SFC079-01	47%	0%	6%	1%	46%	69.1%

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFC079-12	55%	0%	2%	1%	42%	65.4%
SFC080-01	42%	1%	6%	1%	50%	56.4%
SFC080-01 (duplicate)	40%	1%	5%	2%	52%	56.4%
SFC080-12	49%	0%	4%	1%	46%	55.7%
SFC081-01	37%	1%	18%	2%	42%	62.9%
SFC081-12	49%	0%	3%	1%	47%	60.8%
SFC082-01	41%	1%	12%	3%	43%	56.1%
SFC082-12	47%	0%	3%	1%	49%	49.7%
SFC083-01	9%	1%	74%	4%	12%	26.5%
SFC084-01	46%	1%	8%	1%	44%	61.4%
SFC084-12	33%	1%	30%	1%	35%	41.8%
SFC085-01	28%	1%	8%	1%	62%	67%
SFC085-12	46%	1%	3%	1%	49%	50.5%
SFC086-01	41%	1%	13%	1%	44%	65%
SFC086-12	47%	1%	7%	1%	44%	54.2%
SFC087-01	47%	1%	6%	1%	45%	63.5%
SFC087-12	51%	0%	2%	1%	46%	51.2%
SFC088-01	41%	0%	5%	1%	53%	66.3%
SFC088-12	50%	0%	5%	1%	44%	59%
SFC089-01	38%	1%	5%	1%	55%	65.9%
SFC089-12	52%	1%	3%	1%	43%	58.4%
SFC090-01	23%	4%	18%	5%	50%	61.8%
SFC090-01 (duplicate)	26%	2%	47%	3%	22%	61.8%
SFC091-01	37%	3%	6%	2%	52%	73.2%
SFC093-01	39%	4%	10%	5%	42%	72.9%
SFC093-12	45%	2%	10%	3%	40%	66.5%
SFC094-01	36%	2%	15%	1%	46%	53.5%
SFC094-12	46%	0%	2%	1%	51%	51.5%
SFC095-01	34%	2%	18%	2%	44%	49.9%
SFC095-12	46%	0%	5%	2%	47%	49.6%
SFC096-01	39%	1%	16%	2%	42%	57.8%
SFC096-12	41%	1%	20%	1%	37%	47.4%
SFF001-01	13%	0%	65%	4%	18%	25.5%
SFF002-01	35%	0%	16%	1%	48%	48%
SFF003-01	24%	1%	50%	2%	23%	37.2%
SFF004-01	17%	1%	43%	3%	36%	34.5%
SFF005-01	19%	0%	51%	2%	28%	33.3%
SFF005-12	14%	0%	63%	2%	21%	27.5%
SFF006-01	9%	0%	69%	6%	16%	23.7%
SFF007-01	15%	0%	54%	3%	28%	35.7%
SFF008-01	27%	2%	29%	2%	40%	22.8%
SFF009-01	11%	0%	62%	6%	21%	30%
SFF010-01	16%	1%	57%	4%	22%	22.4%
SFF011-01	29%	0%	28%	1%	42%	24.4%
SFF012-01	25%	0%	43%	3%	29%	21.4%
SFF013-01	30%	0%	26%	2%	42%	21.9%
SFF014-01	11%	0%	74%	4%	11%	26.3%

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFF015-01	13%	1%	60%	2%	24%	17.9%
SFF016-01	31%	0%	34%	3%	32%	48%
SFF016-12	42%	0%	15%	2%	41%	50.2%
SFF017-01	26%	1%	30%	4%	39%	45.9%
SFF018-01	31%	1%	34%	2%	32%	55 3%
SFF018-12	35%	1%	29%	2%	33%	52.7%
SFF019-01	30%	0%	31%	2%	37%	58 3%
SFF019-12	42%	0%	16%	1%	41%	52%
SFF020-01	40%	2%	22%	1%	35%	58.3%
SFF020-01 (duplicate)	37%	1%	26%	2%	34%	58.3%
SFF020-12	38%	1%	25%	2%	34%	59%
SFF021-01	38%	2%	22%	1%	37%	51.5%
SFF022-01	36%	2%	25%	1%	36%	58.2%
SFF024-01	21%	2%	49%	2%	26%	39.7%
SFF025-01	8%	1%	71%	2%	18%	24.3%
SFF027-01	22%	1%	40%	2%	35%	31.4%
SFF028-01	28%	0%	13%	1%	58%	60.9%
SFF028-12	55%	0%	2%	0%	43%	53.5%
SFF029-01	52%	1%	16%	1%	30%	53.4%
SFF029-12	61%	0%	1%	1%	37%	50.7%
SFF030-01	31%	2%	29%	2%	36%	59.8%
SFF030-01 (duplicate)	32%	1%	28%	2%	37%	59.8%
SFF030-12	46%	1%	6%	1%	46%	56.4%
SFF031-01	23%	2%	49%	3%	23%	45.5%
SFF032-01	51%	0%	2%	2%	45%	55.1%
SFF032-12	62%	0%	1%	1%	36%	51.5%
SFF033-01	49%	1%	9%	2%	39%	55.5%
SFF033-12	64%	1%	2%	1%	32%	54.2%
SFF034-01	52%	1%	12%	2%	33%	53.1%
SFF034-12	54%	1%	4%	1%	40%	49.8%
SFF035-01	34%	1%	16%	1%	48%	58.6%
SFF035-12	48%	0%	6%	2%	44%	49%
SFF036-01	51%	0%	4%	1%	44%	57.6%
SFF036-12	62%	1%	1%	1%	35%	53.4%
SFF037-01	57%	1%	3%	1%	38%	54.9%
SFF037-12	58%	0%	1%	1%	40%	53%
SFF038-01	47%	1%	10%	1%	41%	54.9%
SFF038-12	53%	1%	4%	1%	41%	52.6%
SFF039-01	44%	1%	6%	1%	48%	59.4%
SFF039-12	52%	1%	7%	1%	39%	54.3%
SFF040-01	46%	1%	8%	2%	43%	54.2%
SFF040-01 (duplicate)	48%	1%	7%	1%	43%	56.9%
SFF040-12	54%	0%	2%	2%	42%	53.9%
SFF041-01	45%	2%	5%	1%	47%	64.9%
SFF042-01	33%	1%	10%	1%	55%	62.7%
SFF042-12	50%	2%	5%	1%	42%	62.8%
SFF043-01	32%	3%	8%	3%	54%	55.1%

TABLE 4-3K. SCUFFLETOWN CREEK: RESULTS OF GRAIN SIZE ANALYSIS

Sample Identification	Clay	Coarse Sand and Larger	Fine Sand	Medium Sand	Silt	Moisture
SFF043-12	41%	0%	4%	1%	54%	49%
SFF044-01	37%	2%	11%	2%	48%	59%
SFF044-12	49%	0%	2%	0%	49%	47.8%
SFF045-01	41%	3%	10%	1%	45%	58.7%
SFF045-12	47%	0%	6%	1%	46%	49%
SFF046-01	44%	1%	10%	1%	44%	56.8%
SFF047-01	26%	4%	20%	7%	43%	55.3%
SFF047-12	40%	0%	4%	1%	55%	48.3%
SFF048-01	44%	0%	4%	2%	50%	58%
SFF048-12	44%	0%	3%	0%	53%	48.3%
SFF049-01	37%	0%	9%	2%	52%	63.9%
SFF049-12	42%	0%	4%	1%	53%	48%
SFF050-01	35%	1%	16%	2%	46%	62.6%
SFF050-01 (duplicate)	35%	1%	14%	3%	47%	62.6%
SFF050-12	42%	1%	6%	1%	50%	51%
SFF051-01	35%	0%	9%	1%	55%	63.5%
SFF051-12	39%	1%	6%	4%	50%	44.5%
SFF052-01	34%	3%	21%	3%	39%	59.6%
SFF052-12	43%	1%	6%	1%	49%	49.5%
SFF053-01	18%	3%	59%	4%	16%	52.5%
SFF053-12	30%	2%	34%	1%	33%	44.4%
SFF054-01	8%	1%	76%	3%	12%	32.8%
SFF054-12	31%	0%	24%	1%	44%	47.5%
SFF055-01	16%	2%	64%	2%	16%	36.9%
SFF055-12	14%	2%	63%	3%	18%	34%
SFF056-01	49%	1%	12%	2%	36%	64.7%
SFF056-12	22%	1%	51%	3%	23%	38.6%
SFF057-01	21%	2%	55%	3%	19%	46.1%
SFF057-12	45%	1%	10%	1%	43%	51%
SFF058-01	26%	4%	49%	4%	17%	54%
SFF059-01	35%	4%	23%	5%	33%	61.2%
SFF059-12	44%	1%	7%	1%	47%	49.8%
SFF060-01	17%	4%	57%	4%	18%	45.1%
SFF060-01 (duplicate)	21%	2%	52%	4%	21%	45.6%
SFF060-12	39%	2%	15%	1%	43%	47.1%
SFF062-01	17%	4%	54%	2%	23%	43.3%

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC001 (0-1 FT)	SFC001 (1-2 FT)	SFC003 (0-1 FT)	SFC003 (1-2 FT)	SFC004 (0-1 FT)	SFC004 (1-2 FT)	SFC005 (0-1 FT)	SFC006 (0-1 FT)	SFC006 (0-1.5 FT)	SFC007 (1-2 FT)	SFC008 (0-1 FT)	SFC008 (1-2 FT)	SFC009 (0-1 FT)	SFC009 (1-2 FT)	SFC010 (0-1 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM	255J	282J													
SW 6010	SELENIUM	7782-49-2	1	AET	2.9	3.2	1.4	1.5	1.2	1.6	1.7	1.7		1.2	1.3B	1.3B	1.1	1.6	1.7
SW 6010	ZINC	7440-66-6	410	ERM															
SW 7470	MERCURY	7439-97-6	0.71	ERM	2.2	2.3		0.77J			0.96J	1.6		0.76	2.4		1.7J	2.1J	2.6J
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL							0.01J								0.0071J
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM								5.1	10	7.8					
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM										0.83					
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET			0.14												
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM								1.1		5.3					
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM									3	3.7					
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM								4.1	6.5	6.6					
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	1.8J						2	3.7	5.8	5.3			2.1J		
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	2.8J						2.5	4.8	5.9	7.8			2.7J		
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	0.85J				0.69		1.4	1.2	2.3	1.4			1.3J		0.69J
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET								3.7	5.8	3.8					
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.37J				0.37		0.84	0.69	1.4	0.9			0.85J		0.51J
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET										0.73			0.14		
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM								11	14						
SW 8270	FLUORENE	86-73-7	0.54	ERM										4					
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	0.8J				0.62		1.3	1.2	2.4	1.6			1.2J		0.7J
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM										11					
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM								10	23	6			3J		

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC010 (1-2 FT)	SFC011 (0-1 FT)	SFC011 (1-2 FT)	SFC012 (0-1 FT)	SFC012 (1-2 FT)	SFC013 (0-1 FT)	SFC013 (1-2 FT)	SFC014 (1-2 FT)	SFC015 (0-1 FT)	SFC017 (0-1 FT)	SFC017 (1-2 FT)	SFC018 (0-1 FT)	SFC018 (1-2 FT)	SFC019 (0-1 FT)	SFC019 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM					219J						303J				
SW 6010	SELENIUM	7782-49-2	1	AET	2	1.7	1.9	1.8	2.4	1.6	1.8	1.4	1.3B	1.3	2.3	1.3	1.1	1.3	2
SW 6010	ZINC	7440-66-6	410	ERM															
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.2J	2	0.89	1.7J	2.6J	1.1J	1.8J	1.7J		1.3J	2.9J				
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL															
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM		4.9J		7											
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET															
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM				1.8											
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM				3.5											
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM		3.3J		6											
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM		4.9J	1.7J	7.5J						1.7J					
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET		7J	1.9J	10J						2.1J					
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET		3.5J	1J	2.9J						0.98J					
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET		4J	1.9J	6J											
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM		1.7J	0.54J	1.4J	0.31J	0.44J				0.69J	0.32J				
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET			0.18	0.74											
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM		6.9J													
SW 8270	FLUORENE	86-73-7	0.54	ERM				1.6											
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET		3.3J	0.96J	2.8J		0.62J				0.94J					
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM				11											
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM		8.6J	3.5J	8											

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC020 (0-1 FT)	SFC020 (1-2 FT)	SFC021 (0-1 FT)	SFC021 (1-1.75 FT)	SFC022 (0-1 FT)	SFC023 (0-1 FT)	SFC023 (1-2 FT)	SFC024 (1-1.5 FT)	SFC025 (0-1 FT)	SFC026 (0-1 FT)	SFC026 (1-2 FT)	SFC027 (0-1 FT)	SFC027 (1-2 FT)	SFC029 (0-1 FT)	SFC029 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET	1.4	1.9B	1.1B	1.6B	1.4	1.6	1.4	1.2	1.7	1.5	1.5		1.6B	1.3B	1.1B
SW 6010	ZINC	7440-66-6	410	ERM															
SW 7470	MERCURY	7439-97-6	0.71	ERM	0.72														
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.0092J		0.0031J						0.0041						
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET															
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM															
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	2.3J											2J			
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	3.4J		2.1									2.9J			
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	0.97J		0.87									0.76J			
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET	2.2J														
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.5J		0.51									0.42J			
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	0.19		0.13									0.15			
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	1J		0.93									0.79J			
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM															

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC030 (0-1 FT)	SFC030 (1-2 FT)	SFC031 (0-1 FT)	SFC032 (0-1 FT)	SFC032 (1-2 FT)	SFC033 (0-1 FT)	SFC033 (1-2 FT)	SFC035 (0-1.25 FT)	SFC038 (0-1.3 FT)	SFC039 (0-1 FT)	SFC039 (1-2 FT)	SFC040 (0-1 FT)	SFC040 (1-2 FT)	SFC041 (0-1 FT)	SFC041 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET	1.4	1.6	1.5B	1.7B	1.3B	1.5B	1.6B	1.2B	1.5B	1.6B	1.6B	1.2B	1.7B	1.7B	1.6B
SW 6010	ZINC	7440-66-6	410	ERM															
SW 7470	MERCURY	7439-97-6	0.71	ERM								0.78							
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.0076J														
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET															
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM															
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM															
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET															
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET															
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET															
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET						0.073									
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM															
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET															
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET															
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM															

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC042 (0-1 FT)	SFC042 (1-2 FT)	SFC043 (0-1 FT)	SFC043 (1-2 FT)	SFC044 (0-1 FT)	SFC044 (1-2 FT)	SFC045 (0-1 FT)	SFC045 (1-2 FT)	SFC046 (1-2 FT)	SFC047 (0-1 FT)	SFC047 (1-2 FT)	SFC048 (0-1 FT)	SFC048 (1-2 FT)	SFC049 (0-1 FT)	SFC049 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET	1.8B	1.5B	1.6B	1.5B	1.6	1.4	1.3	1.3	1.1	1.9	1.7	1.6	1.4	1.7	2
SW 6010	ZINC	7440-66-6	410	ERM															
SW 7470	MERCURY	7439-97-6	0.71	ERM															0.77
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL															
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET															
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM															
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM														1.7J	1.8J
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET														2.2J	2.6J
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET														0.9J	0.81J
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET															
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															0.093
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM														0.47J	0.47J
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET														0.12	0.14
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET														0.88J	0.81J
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM															2.7

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC050 (0-1 FT)	SFC050 (1-2 FT)	SFC054 (0-1 FT)	SFC054 (1-1.75 FT)	SFC057 (0-1 FT)	SFC057 (1-2 FT)	SFC058 (0-1 FT)	SFC058 (1-2 FT)	SFC059 (0-1 FT)	SFC059 (1-2 FT)	SFC061 (0-1 FT)	SFC061 (1-2 FT)	SFC062 (0-1 FT)	SFC062 (1-2 FT)	SFC063 (0-1 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM							400J								
SW 6010	LEAD	7439-92-1	218	ERM							305	227	247	277	270				
SW 6010	SELENIUM	7782-49-2	1	AET	1.3J	1.3J	1.6	2.8	2.2J	2.2J	2.3	2.6	2	2.3	2.1	2.2	1.9	2	1.4
SW 6010	ZINC	7440-66-6	410	ERM	431	445					832J	412J	620J	529J	550				559J
SW 7470	MERCURY	7439-97-6	0.71	ERM		0.89J	1.2	1.3	3.1		3.1	1.5	2.8	3.6	2.3	1.8	1.3		1.2J
SW 8081	4,4'-DDD	72-54-8	0.02	ERM									0.033J						
SW 8081	4,4'-DDE	72-55-9	0.027	ERM									0.091J						
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.0094J	0.0073J							0.018J	0.0089					
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM									0.24J						
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.16		0.27		0.19		0.35	0.31	0.18	0.44	0.17	0.21	0.13		
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	1.8	2													
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	2	1.7													
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	2.5	2.4			2.6J		2.1J								1.9J
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	0.72J	0.69			0.91J								0.91J		1J
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET															
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET									0.14	0.68					
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET	2.6B														
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.42J	0.37			0.37J								0.38J		0.43J
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	0.15	0.16													0.12J
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	0.94	0.69											0.85J		1J
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM	3.1	4.6			2.8J										

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC063 (1-2 FT)	SFC064 (0-1 FT)	SFC064 (1-2 FT)	SFC065 (0-1 FT)	SFC065 (1-2 FT)	SFC066 (0-1 FT)	SFC066 (1-2 FT)	SFC067 (0-1 FT)	SFC067 (1-2 FT)	SFC068 (0-1 FT)	SFC068 (1-2 FT)	SFC069 (0-1 FT)	SFC069 (1-2 FT)	SFC070 (0-1 FT)	SFC070 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET									22J						
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM		290J	255J	250J		242J			1210J					247	
SW 6010	SELENIUM	7782-49-2	1	AET	1.2	3.2	3.1	3	2.4	1.8	1.4	2.3	1.3B	2.3	1.3	1.9	1.5	1.4J	1.1J
SW 6010	ZINC	7440-66-6	410	ERM		757J	480J	641J		547J								709	
SW 7470	MERCURY	7439-97-6	0.71	ERM		2.2	2.2	1.9	0.76	1.9		1		1.5		1.3		2.2	
SW 8081	4,4'-DDD	72-54-8	0.02	ERM														0.035	
SW 8081	4,4'-DDE	72-55-9	0.027	ERM														0.045J	
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM														0.015J	
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL														0.017J	
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM														0.2J	
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM						6.2									
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET						0.3								0.84	
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM						1.2									
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM						5.3									
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM						4.6J									
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET						5.9J								2.9	
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET						2.3J								0.71	
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET						4.5J									
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET			1.5												
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM						1.3J									
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET															
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM						11									
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET						2.4J								0.69	
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM						5.3									
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM						12									

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC071 (0-1 FT)	SFC072 (0-1 FT)	SFC072 (1-1.5 FT)	SFC073 (0-1 FT)	SFC073 (1-2 FT)	SFC074 (0-1 FT)	SFC075 (0-1.2 FT)	SFC076 (0-1 FT)	SFC076 (1-2 FT)	SFC077 (0-1 FT)	SFC077 (1-2 FT)	SFC078 (0-1 FT)	SFC078 (1-2 FT)	SFC079 (0-1 FT)	SFC079 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM		293J	236J	237J		236J	257J		317J		237J	233J	326J	242J	
SW 6010	SELENIUM	7782-49-2	1	AET	1.6	2.9	2.9	3	2.7	2.3	2.5	2.1	2.1	2	2.5	1.7	2	2.1	1.9
SW 6010	ZINC	7440-66-6	410	ERM	486J	763J	532J	672J		583J	555J	499J	679J	622J		563J	559J	601J	
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.9J	1.4	3.6	1.3	0.8	1.3	2.8	0.91	2.5	2.4	3.4	2.4	3.2	2.5	2.5
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL										0.014	0.0075J				
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM									5.8J	6.8		5.4J	3.1J	4.2J	
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.14				0.16	0.14	0.29		1.2	0.25			0.4	0.49	0.2
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM									0.77			0.67	0.61		
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM												0.83			
SW 8270	ANTHRACENE	120-12-7	1.1	ERM									1.7	1.2		1.6J	1.4J	1.2	
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM								2J	4.3J	4.2		5.2J	2.9J	3.6J	
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM								2.4J	3.5J	4.1J		4.4J	2.1J	3.6J	
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET								4.3J	5.8J	8.7J	2.1J	8J	3.3J	5.9J	
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	0.68J						0.69J	2J	2.2J	2.1J		3.9J	1.6J	2.6J	1.1J
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET								3J	4J	2.8J		4.9J	2.4J	4J	
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET									0.26J						
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.3J								1.2J	0.73J		1.8J	0.82J	1.1J	0.48J
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET							0.15		0.37	0.3			0.26	0.36	0.16J
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM									12	9.6		12J	7.7J	8.5	
SW 8270	FLUORENE	86-73-7	0.54	ERM									0.81						
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET							0.62J	2J	2J	2J		3.6J	1.6J	2.4J	0.96J
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM									3.3			1.8J	1.8J		
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM								4.8J	9.5J	9.6		11J	5.3J	9.3J	

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC080 (0-1 FT)	SFC080 (1-1.5 FT)	SFC081 (0-1 FT)	SFC081 (1-2 FT)	SFC082 (0-1 FT)	SFC082 (1-2 FT)	SFC084 (0-1 FT)	SFC084 (1-2 FT)	SFC085 (0-1 FT)	SFC085 (1-2 FT)	SFC086 (1-2 FT)	SFC087 (0-1 FT)	SFC087 (1-2 FT)	SFC088 (0-1 FT)	SFC088 (1-1.8 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM									288J			256J		289J	327J
SW 6010	SELENIUM	7782-49-2	1	AET	2	1.8	2.3	2.1	1.6	2.1	2.6	1.4	2	2.2	1.7	1.5	1.3	2.8	3.3
SW 6010	ZINC	7440-66-6	410	ERM			582	674			433J		514		422J	704J		724J	735J
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.3J	0.99J			0.82		1		1.1J			1.4J		1.7	1.1
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM									0.037						
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.0041	0.0094J							0.014	0.0069					
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.24	0.16							0.17		0.13	0.17			0.12
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM															
SW 8270	BENZO(A)PYRENE	50-32-8	1.6	ERM															
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET									1.9J						
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	0.83J								0.84J						
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET															
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.41J								0.5J			0.29			
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET															
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	0.77J								0.8J						
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM															

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFC089 (0-1 FT)	SFC089 (1-2 FT)	SFC090 (0-1 FT)	SFC091 (0-1.5 FT)	SFC093 (0-1 FT)	SFC094 (0-1 FT)	SFC094 (1-1.9 FT)	SFC095 (0-1 FT)	SFC095 (1-2 FT)	SFC096 (0-1 FT)	SFC096 (1-2 FT)	SFF001 (0-1 FT)	SFF002 (0-1 FT)	SFF003 (0-1 FT)	SFF007 (0-1 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM	278J	285J						223							
SW 6010	SELENIUM	7782-49-2	1	AET	3.2	3.9	2.2	2.6	2.2	2.6	2.5	1.3	2.3	1.7	1.1B	1.1B	1.4	1.3B	1.2B
SW 6010	ZINC	7440-66-6	410	ERM	719J	570J													
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.5	2.1	1						1.3	0.85					
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL			0.006J					0.013J							
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM															
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET			1.9	0.12											
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM															
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM															
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM															
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM															
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET								2.3J							
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET								0.77J							
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET															
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM								0.37J							
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET								0.14							
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM															
SW 8270	FLUORENE	86-73-7	0.54	ERM															
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET								0.74J							
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM															
SW 8270	PHENOL	108-95-2	0.42	AET			0.48												
SW 8270	PYRENE	129-00-0	2.6	ERM															

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFF016 (0-1 FT)	SFF018 (0-1 FT)	SFF018 (1-2 FT)	SFF019 (0-1 FT)	SFF019 (1-2 FT)	SFF020 (0-1 FT)	SFF020 (1-2 FT)	SFF021 (0-1 FT)	SFF022 (0-1 FT)	SFF024 (0-1 FT)	SFF025 (0-1 FT)	SFF028 (0-1 FT)	SFF028 (1-2 FT)	SFF029 (0-1 FT)	SFF029 (1-1.5 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET		1.7	1.3B	1.5	2	2	1.4	1.4B	1.1	1.1		1.9	1.9	1.7	1.7
SW 6010	ZINC	7440-66-6	410	ERM	420J					427J									
SW 7470	MERCURY	7439-97-6	0.71	ERM		0.78			1.5	0.86		0.72	2		0.9J				
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM						0.039J	0.032J								
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL		0.019J	0.01			0.031J	0.013								
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM						0.29J									
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM	6.6	6.1	6.5	6.2	6.1	7.3	5.7		11						
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM						1.2									
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET															
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM	1.1	0.93	1.4		0.83	1.4	1								
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM	2.4	1.9	1.9	1.6	1.8	2.4	2.3		2.4						
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	5.5	4.4	4.7	4.3	4.6	4.9	3.9		6.7						
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	5	4.8	3.9	5.9J	4.7J	4.3J	4.1J		9.8						
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	6.8	8.4	6.4	7.8J	6.5J	6.5J	6J		17						
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	2.9	1.7	1.5	2.9J	2J	1.9J	2J		4.6						
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET	5.5	2.9	2.1	4.5J	4.3J	4.7	4J		5.9						
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	1.7	0.83	0.72	1.4J	1.2J	0.95J	1J		1.8						
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	0.63			0.37	0.39	0.46	0.4		0.62	0.16					
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM	15	13	13	6	13	15	12		15						
SW 8270	FLUORENE	86-73-7	0.54	ERM	0.74				0.65	0.67	0.95								
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	2.9	1.8	1.5	3J	2.1J	1.9J	2J		4.6						
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM	2.7	1.6		2.1	2.1	5.1	6.1		2	1.9					
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM	15	12	9.9	9.3	11	14	10		20						

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFF030 (0-1 FT)	SFF030 (1-1.7 FT)	SFF031 (0-1 FT)	SFF032 (0-1 FT)	SFF032 (1-2 FT)	SFF033 (0-1 FT)	SFF033 (1-1.75 FT)	SFF034 (0-1 FT)	SFF034 (1-1.6 FT)	SFF035 (0-1 FT)	SFF035 (1-2 FT)	SFF036 (0-1 FT)	SFF036 (1-1.8 FT)	SFF037 (0-1 FT)	SFF037 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET	2	1.7	1.6	1.6	2	1.7	1.6	1.6	1.8	1.8	1.6	1.4	1.8	2	1.6
SW 6010	ZINC	7440-66-6	410	ERM	490				585										
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.2				1.6										
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.013J	0.0074J								0.0051				0.0046J	
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM	3.9				6										
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.15														
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM					1										
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM	1.3				2.6										
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	2.4				3.9										
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	3.7				3.3										
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	7.5	2.7J			6.9										
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	2.2	0.68J			1.9										
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET	2.4				2.5										
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.71	0.28J													
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	0.37	0.15			0.5	0.12									
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM	5.4				15										
SW 8270	FLUORENE	86-73-7	0.54	ERM					0.67										
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	2.3	0.68J			2										
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM	1.6				3										
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM	7.8	3.2			12										

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFF038 (0-1 FT)	SFF038 (1-1.7 FT)	SFF039 (0-1 FT)	SFF039 (1-2 FT)	SFF040 (0-1 FT)	SFF040 (1-1.7 FT)	SFF041 (0-1 FT)	SFF042 (0-1 FT)	SFF042 (1-1.8 FT)	SFF043 (0-1 FT)	SFF043 (1-2 FT)	SFF044 (0-1 FT)	SFF044 (1-1.9 FT)	SFF045 (0-1 FT)	SFF045 (1-1.5 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM			227				250	229	263						
SW 6010	SELENIUM	7782-49-2	1	AET	1.7	1.6	2.1	2.3	1.8	1.7	1.5J	1.7J	1.9J	2.1	1.6	2.2	2	2.3	2
SW 6010	ZINC	7440-66-6	410	ERM			713				617	718	623						
SW 7470	MERCURY	7439-97-6	0.71	ERM			1.4			1.4J	2.7J	1.7J	2.5J	1		1.3		1.2	
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL					0.0041	0.0089								0.0047J	
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM	3.3				3.7J		3.4		4.4						
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.17				0.35		0.63	0.5	0.51	4.9				0.82	
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM							0.52		0.58						
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM	0.87														
SW 8270	ANTHRACENE	120-12-7	1.1	ERM	1.9				1.4		1.2		1.5						
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	2.6				2.9J		2.3	1.7	3.3						
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	3.1			1.9	2.7J		1.9		2.9	1.7					
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	4.5			3.3	4.3J		3.6	2.7J	4.5	2.3					
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	1.8			1.2	1.4J	0.84J	1.1	1J	1.3	1					
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET					2.8J		2	2J	2.6						
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET															
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	0.69			0.42	0.6J	0.41J	0.49	0.58J	0.69	0.46					
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	1.1			0.14	0.31	0.14	0.25	0.2	0.24						
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM	5.3				6.6		5.8		6.9						
SW 8270	FLUORENE	86-73-7	0.54	ERM	1.3								0.56						
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	1.7			1.1	1.5J	0.81J	1	1J	1.5	0.96					
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM	6				2.1		2.1		2.8						
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM	7 1			4.1	6J		4.9	4	6.2						

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFF046 (0-1 FT)	SFF047 (0-1 FT)	SFF047 (1-2 FT)	SFF048 (0-1 FT)	SFF048 (1-2 FT)	SFF049 (0-1 FT)	SFF049 (1-2 FT)	SFF050 (0-1 FT)	SFF050 (1-2 FT)	SFF051 (0-1 FT)	SFF051 (1-2 FT)	SFF052 (0-1 FT)	SFF052 (1-2 FT)	SFF053 (0-1 FT)	SFF053 (1-2 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET															
SW 6010	COPPER	7440-50-8	270	ERM															
SW 6010	LEAD	7439-92-1	218	ERM															
SW 6010	SELENIUM	7782-49-2	1	AET	2.2	2.6J	2.3J	2.5J	1.7J	2.4	1.7	2.7	2.1	2.4	1.7	2.1	2	1.9	1.7
SW 6010	ZINC	7440-66-6	410	ERM								518		454					
SW 7470	MERCURY	7439-97-6	0.71	ERM		1.2	0.74	1.1		1.2		1.9		1.3		0.75		1.5	
SW 8081	4,4'-DDD	72-54-8	0.02	ERM															
SW 8081	4,4'-DDE	72-55-9	0.027	ERM															
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM															
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL								0.0048		0.0052J					
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM															
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM															
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM														4.9	
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM															
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET								0.39		0.58					
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM														0.7	
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM															
SW 8270	ANTHRACENE	120-12-7	1.1	ERM														2.7	
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM														5.2	
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM														5	
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET		2.6J												7.5	
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET		1.1J												3.4	
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET														2.3	
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET															
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET											1.7B				
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM		0.45J												1.2	
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET														0.35	
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM														10	
SW 8270	FLUORENE	86-73-7	0.54	ERM														0.89	
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET														3.5	
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM														7	
SW 8270	PHENOL	108-95-2	0.42	AET															
SW 8270	PYRENE	129-00-0	2.6	ERM		2.8												13	

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-3M. SCUFFLETOWN CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SFF054 (0-1 FT)	SFF054 (1-2 FT)	SFF055 (0-1 FT)	SFF055 (1-1.3 FT)	SFF056 (0-1 FT)	SFF056 (1-2 FT)	SFF057 (0-1 FT)	SFF057 (1-2 FT)	SFF058 (0-1 FT)	SFF059 (0-1 FT)	SFF059 (1-2 FT)	SFF060 (0-1 FT)	SFF060 (1-2 FT)	SFF062 (0-1 FT)
SW 6010	ANTIMONY	7440-36-0	9.3	AET														
SW 6010	COPPER	7440-50-8	270	ERM														
SW 6010	LEAD	7439-92-1	218	ERM														
SW 6010	SELENIUM	7782-49-2	1	AET	1.3	1.6		2.1	1.6	1.5	1.3	1.7	1.6	2.1B	1.4B	1.4	2	2
SW 6010	ZINC	7440-66-6	410	ERM														
SW 7470	MERCURY	7439-97-6	0.71	ERM	1				1					0.85		0.9		
SW 8081	4,4'-DDD	72-54-8	0.02	ERM														
SW 8081	4,4'-DDE	72-55-9	0.027	ERM														
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM														
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL	0.0083		0.0066J	0.01								0.0055		
SW 8082	AROCLOR 1254	11097-69-1	0.18	ERM														
SW 8082	AROCLOR 1260	11096-82-5	0.18	ERM														
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM														
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM														
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET				0.99						0.37				
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM														
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM														
SW 8270	ANTHRACENE	120-12-7	1.1	ERM														
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM														
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM														
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET				1.9J										
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET														
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET														
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET										0.12J				
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET														
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM														
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET				0.12										
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM														
SW 8270	FLUORENE	86-73-7	0.54	ERM														
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET														
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM														
SW 8270	PHENOL	108-95-2	0.42	AET														
SW 8270	PYRENE	129-00-0	2.6	ERM														

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-4A. SCOTTS CREEK SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Scotts Creek (0-2ft) Sample ID	SVOC	Pest/PCB	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EA Lab Report SDG#
SCC001	X		X	X			X		990449
SCC002	X	X	X	X			X	X	990449
SCC002FD	X	X	X	X					990449
SCC003	X	X	X	X			X		990401
SCC004	X		X	X			X		990401
SCC005	X		X	X			X		990401
SCC006	X		X	X			X		990401
SCC007	X		X	X			X		990401
SCC008	X		X	X			X		990449
SCC009	X		X	X			X		990401
SCC010	X		X	X			X		990484
SCC011	X		X	X			X		990484
SCC012	X	X	X	X	X	X	X		990449
SCC013	X		X	X			X		990401
SCC014	X		X	X			X		990449
SCC015	X		X	X			X		990449
SCC016	X		X	X			X		990449
SCF001	X		X	X			X		990484
SCF002	X		X	X			X		990449
SCF003	X		X	X			X		990449
SCF004	X		X	X			X		990484
SCF005	X	X	X	X	X	X	X		990484
SCF006	X		X	X			X		990484
SCF007	X		X	X			X		990484
SCF008	X		X	X			X	X	990484
SCF009	X	X	X	X			X		990484
SCF011	X		X	X			X		990401
SCF012	X		X	X			X		990401
SCF013	X		X	X			X		990484
SCF014	X	X	X	X	X	X	X		990484
SCF015	X		X	X			X		990484
SCF016	X		X	X			X		990484

TABLE 4-4M. SCOTTS CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SCC001 (0-2 FT)	SCC002 (0-2 FT)	SCC003 (0-2 FT)	SCC004 (0-2 FT)	SCC005 (0-0.83 FT)	SCC006 (0-2 FT)	SCC007 (0-2 FT)	SCC008 (0-0.85 FT)	SCC009 (0-2 FT)	SCC010 (0-1.5 FT)	SCC011 (0-1.8 FT)	SCC012 (0-1.7 FT)	SCC013 (0-2 FT)
SW 6010	LEAD	7439-92-1	218	ERM	243J		258							268			
SW 6010	SELENIUM	7782-49-2	1	AET	2.2	2.1	2.5	1.8	1.5	1.6	1.7		1.5	2.4	2.2	2	1.7
SW 6010	ZINC	7440-66-6	410	ERM	488J		635							435			
SW 7470	MERCURY	7439-97-6	0.71	ERM	0.92		1.3B	1.5B						1.7		0.98	1.1B
SW 8081	4,4'-DDD	72-54-8	0.02	ERM			0.031J										
SW 8081	4,4'-DDE	72-55-9	0.027	ERM			0.063J										
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM													
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL		0.0052J	0.019										
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM													
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM													
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET	0.6		0.14					0.18		0.19		0.21	0.45
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM													
SW 8270	ANTHRACENE	120-12-7	1.1	ERM													
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM													
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM													
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET													1.9J
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET													1J
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET													
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET												0.13J	
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET				1.4									1.4J
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM													0.3J
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET													0.17
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM													
SW 8270	FLUORENE	86-73-7	0.54	ERM													
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET													1J
SW 8270	NAPHTHALENE	91-20-3	2.1	ERM													
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM													
SW 8270	PHENOL	108-95-2	0.42	AET													
SW 8270	PYRENE	129-00-0	2.6	ERM													3.1J

* If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-4M. SCOTTS CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SCC014 (0-2 FT)	SCC015 (0-2 FT)	SCC016 (0-2 FT)	SCF001 (0-1 FT)	SCF002 (0-1 FT)	SCF003 (0-2 FT)	SCF004 (0-1.5 FT)	SCF005 (0-2 FT)	SCF006 (0- FT)	SCF007 (0-2 FT)	SCF008 (0-1 FT)	SCF009 (0-1.7 FT)	SCF012 (0-2 FT)
SW 6010	LEAD	7439-92-1	218	ERM		287J	629J				262J	234J		270J			
SW 6010	SELENIUM	7782-49-2	1	AET	2.3	1.6	2.2	1.5		1.9	2	3	3	2.1	1.6	2	1.5B
SW 6010	ZINC	7440-66-6	410	ERM		503J	809J							505J			
SW 7470	MERCURY	7439-97-6	0.71	ERM		0.95	1.1					0.74					
SW 8081	4,4'-DDD	72-54-8	0.02	ERM								0.037J				0.022J	
SW 8081	4,4'-DDE	72-55-9	0.027	ERM													
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM								0.0071J				0.0081	
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL								0.0087J				0.013	
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM													
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM													
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET			0.15					0.14		0.13			
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM													
SW 8270	ANTHRACENE	120-12-7	1.1	ERM													
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM													
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM													
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET										1.9J			
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET			0.77J										
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET													
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET			0.11J									0.071	
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET			1.4J										
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM			0.29J										
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET										0.29	0.14		
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM													
SW 8270	FLUORENE	86-73-7	0.54	ERM													
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET			0.89J										
SW 8270	NAPHTHALENE	91-20-3	2.1	ERM													
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM										2.3J			
SW 8270	PHENOL	108-95-2	0.42	AET					0.44								
SW 8270	PYRENE	129-00-0	2.6	ERM										3.3J			

* If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-4M. SCOTTS CREEK: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	SCF013 (0-1.5 FT)	SCF014 (0-1.5 FT)	SCF015 (0-1.5 FT)	SCF016 (0-1.7 FT)
SW 6010	LEAD	7439-92-1	218	ERM	247J	633	550	611
SW 6010	SELENIUM	7782-49-2	1	AET	2.8	2.2	2.9	3.1
SW 6010	ZINC	7440-66-6	410	ERM	433J	598	901	857
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.2		2.8	2.9
SW 8081	4,4'-DDD	72-54-8	0.02	ERM				
SW 8081	4,4'-DDE	72-55-9	0.027	ERM				
SW 8081	GAMMA-CHLORDANE	5103-74-2	0.006	ERM				
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL		0.013J		
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM	13J			
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM	2.6			
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET				0.14
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM	2.4			
SW 8270	ANTHRACENE	120-12-7	1.1	ERM	5.7			
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	10J			
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	8.8J			
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	13J			
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	3.5J			
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET	4.8J			
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET				
SW 8270	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1.3	AET	2.3J			
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM	1.5J			
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	5			
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM	17			
SW 8270	FLUORENE	86-73-7	0.54	ERM	4.4			
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	3.6J			
SW 8270	NAPHTHALENE	91-20-3	2.1	ERM	7			
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM	27			
SW 8270	PHENOL	108-95-2	0.42	AET				
SW 8270	PYRENE	129-00-0	2.6	ERM	30J			

* If detected analyte has no ERM value, either PEL or AET minimum value was used for compansons.

Bolded results=diluted samples

J=estimated B=detected in blank

TABLE 4-5M. EAST OF CAMPOSTELLA BRIDGE: CONCENTRATIONS OF DETECTED ANALYTES (MG/MG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	CBC003 (0-2 FT)	CBC004 (0-2 FT)	CBC005 (0-1.5 FT)	CBC006 (0-1.25 FT)	CBC007 (0-2 FT)	CBC008 (0-1.4 FT)	CBC009 (0-1.6 FT)	CBC010 (0-2 FT)	CBC011 (0-2 FT)	CBC012 (0-2 FT)	CBC013 (0-2 FT)	CBC014 (0-2 FT)	CBC015 (0-1.5 FT)
SW 6010	SELENIUM	7782-49-2	1	AET	1.2J	1.5J	1.1J	1.4J	1.9J	2.4J	2.1J	1.9J	1.9J	1.7J	2.1	1.6	1.9
SW 6010	ZINC	7440-66-6	410	ERM											437		
SW 7470	MERCURY	7439-97-6	0.71	ERM										1.2	1.3B		
SW 8081	4,4'-DDD	72-54-8	0.02	ERM													
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL													
SW 8082	AROCLOR 1016	12674-11-2	0.18	ERM													
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET													
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM													
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET													
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET													
SW 8270	FLUORENE	86-73-7	0.54	ERM													
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM													
SW 8270	PYRENE	129-00-0	2.6	ERM													

*If detected analyte has no ERM value, the minimum value of either the PEL or AET was used for comparisons.

J = estimated B = detected in blank

TABLE 4-5M. EAST OF CAMPOSTELLA BRIDGE: CONCENTRATIONS OF DETECTED ANALYTES (MG/MG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	CBC016 (0-2 FT)	CBC017 (0-2 FT)	CBC018 (0-2 FT)	CBC019 (0-2 FT)	CBC020 (0-2 FT)	CBC022 (0-2 FT)	CBC023 (0-2 FT)	CBC024 (0-2 FT)	CBC025 (0-1.25 FT)	CBF001 (0-1.7 FT)	CBF003 (0-2 FT)	CBF004 (0-2 FT)	CBF005 (0-1.5 FT)
SW 6010	SELENIUM	7782-49-2	1	AET	2.3	1.9	1.7	2	1.9	2	1.8	2.1	1.6	1.6	1.6	1.2	
SW 6010	ZINC	7440-66-6	410	ERM	457												
SW 7470	MERCURY	7439-97-6	0.71	ERM	1.1B										1.3		
SW 8081	4,4'-DDD	72-54-8	0.02	ERM													0.022J
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL													0.008J
SW 8082	AROCLOR 1016	12674-11-2	0.18	ERM													0.19
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET													0.19
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM													
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET												0.19	
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET													
SW 8270	FLUORENE	86-73-7	0.54	ERM													
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM													
SW 8270	PYRENE	129-00-0	2.6	ERM													

*If detected analyte has no ERM value, the minimum value of either the PEL or AET was used for comparisons.

J = estimated B = detected in blank

TABLE 4-5M. EAST OF CAMPOSTELLA BRIDGE: CONCENTRATIONS OF DETECTED ANALYTES (MG/MG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	CBF007 (0-2 FT)	CBF008 (0-2 FT)
SW 6010	SELENIUM	7782-49-2	1	AET	2.1J	1.7J
SW 6010	ZINC	7440-66-6	410	ERM		
SW 7470	MERCURY	7439-97-6	0.71	ERM		1
SW 8081	4,4'-DDD	72-54-8	0.02	ERM		
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL		
SW 8082	AROCLOR 1016	12674-11-2	0.18	ERM		
SW 8270	4-METHYLPHENOL	106-44-5	0.11	AET		
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM		1.1
SW 8270	BENZYL BUTYL PHTHALATE	85-68-7	0.063	AET		
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET		0.4
SW 8270	FLUORENE	86-73-7	0.54	ERM		0.99
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM		3.6
SW 8270	PYRENE	129-00-0	2.6	ERM		3.1J

*If detected analyte has no ERM value, the minimum value of either the PEL or AET was used for comparisons.

J = estimated B = detected in blank

TABLE 4-6A EPPINGER AND RUSSELL SUMMARY OF ANALYSES CONDUCTED FOR EACH SAMPLE

Eppinger & Russel (0-2ft) Sample ID	SVOC	Pest/PCBs	PP Metals	TOC	PCB Congeners	PCT Aroclors	Grain Size	Grain Size Duplicate	EPA Narragansett	EA Lab Report SDG#
ERF011	X		X	X	X	X	X		X	990265
ERC001	X		X	X			X		X	990265
ERC004	X	X	X	X	X	X	X	X	X	990265
ERC004FD	X	X	X	X						990265
ERC005	X		X	X			X		X	990265
ERC008	X		X	X	X	X	X		X	990265

TABLE 4-6M. EPPINGER AND RUSSELL: CONCENTRATIONS OF DETECTED ANALYTES (MG/KG) EXCEEDING EFFECTS RANGE MEDIAN*

Method	Analyte	Cas Number	DQO Value*	DQO Source	ERC001 (0-1.75 FT)	ERC004 (0-2 FT)	ERC005 (0-2 FT)	ERC008 (0-2 FT)	ERF011 (0-2 FT)
SW 6010	LEAD	7439-92-1	218	ERM		251J			
SW 6010	SELENIUM	7782-49-2	1	AET	1.8	1.6	1.8	1.4	1.5
SW 8081	4,4'-DDT	50-29-3	0.007	ERM		0.0073J			
SW 8081	DIELDRIN	60-57-1	0.008	ERM		0.012J			
SW 8081	HEPTACHLOR EPOXIDE	1024-57-3	0.003	PEL		0.02J			
SW 8270	1,2-BENZPHENANTHRACENE	218-01-9	2.8	ERM	23J	34J	20J	19J	5
SW 8270	2-METHYLNAPHTHALENE	91-57-6	0.67	ERM	19	45	14	2.1	13
SW 8270	ACENAPHTHENE	83-32-9	0.5	ERM	71	34	41	7 1	20
SW 8270	ACENAPHTHYLENE	208-96-8	0.64	ERM		4.7		0.79	
SW 8270	ANTHRACENE	120-12-7	1.1	ERM	56	33	71	15J	13
SW 8270	BENZ[A]ANTHRACENE	56-55-3	1.6	ERM	21J	38J	17J	13J	4.5
SW 8270	BENZO[A]PYRENE	50-32-8	1.6	ERM	11	28J	9.1J	10J	2.6
SW 8270	BENZO[B]FLUORANTHENE	205-99-2	1.8	AET	9.8	28J	9.4J	11J	2.9
SW 8270	BENZO[GHI]PERYLENE	191-24-2	0.67	AET	4.6	15J	4J	5J	0.84
SW 8270	BENZO[K]FLUORANTHENE	207-08-9	1.8	AET	10	20J	8.5J	9.1J	2.9
SW 8270	DIBENZ[A,H]ANTHRACENE	53-70-3	0.26	ERM		9.6J		2.7J	
SW 8270	DIBENZOFURAN	132-64-9	0.11	AET	38	39	29	2.5	17
SW 8270	FLUORANTHENE	206-44-0	5.1	ERM	87	84	67	40J	26
SW 8270	FLUORENE	86-73-7	0.54	ERM	52	44	51	6.1	19
SW 8270	INDENO[1,2,3-CD]PYRENE	193-39-5	0.6	AET	4.3	15J	3.9J	5.1J	0.96
SW 8270	NAPHTHALENE	91-20-3	2.1	ERM	13	220	17		41
SW 8270	PHENANTHRENE	85-01-8	1.5	ERM	110	220	110	18J	39
SW 8270	PYRENE	129-00-0	2.6	ERM	64J	57J	54J	33J	15

*If detected analyte has no ERM value, either PEL or AET minimum value was used for comparisons.

Bolded results=diluted samples

J=estimated B=detected in blank

5. OBSERVATIONS, SUGGESTIONS, AND RECOMMENDATIONS

Overall, gravity coring was a successful method for recovering sediment from the 0-2 ft depth at three of the four sampling areas in the Phase I Sediment Investigation. Scotts Creek, East of Campostella Bridge, and the previous Eppinger and Russell site yielded sufficient 0-2 ft sediment recoveries for the majority of the sampling locations. Sediments in these areas were predominantly silty and soft, with little sand and shell fragments. Twenty eight percent of targeted stations in Scuffletown Creek yielded only a 0-1 ft sediment sample; the 1-2 ft horizon was not sampled due to insufficient recovery (Figure 2-1D). Recovery of the 1-2 ft depth interval in Scuffletown Creek was difficult due to sand and shell fragments distributed throughout the area. Only five of the 181 targeted locations in Scuffletown Creek, however, yielded no sediment recovery (Figures 2-1E). These stations were characterized by hard sand and shell fragments; two were situated south of the Jordan lift bridge, one was located near the entrance to Scuffletown Creek, and one was located east of the train bridge.

The existing analytical data, once interpreted and spatially evaluated, will provide a comprehensive picture of the lateral distribution of the compounds of potential concern in the upper 0-2 ft of sediment. This data will be useful in focusing the second phase (i.e., Phase II) of sampling.

The objective of the Phase II investigation is to comprehensively evaluate the lateral and vertical extent of contamination in Scuffletown Creek. Based upon observations conducted during the Phase I field effort, vibracoring would be the best method for collecting sediment below the 1-ft horizon for the Phase II investigation. Vibracoring allows the sampler to have better vertical control (i.e. specific sedimentary horizons can be targeted). Vibracoring also allows for greater penetration depth than gravity or hand coring, and horizons below 2 ft of the sediment surface can easily be obtained. Vibracoring does, however, involve more time per station than gravity or hand coring. Steel pipe casing holding the core liner must be connected in increments as the vibracorer drives the pipe into the sediment.

In addition to analytical testing, toxicity testing of sediments from Scuffletown Creek, Scotts Creek, and East of Campostella Bridge is proposed for the Phase II investigation. Toxicity testing requires a greater volume of sediment than analytical testing. Thus, sampling for Phase II will require greater effort per station to obtain the sediment volume required for the toxicological testing. Required sediment volume will be dependent upon the suite of tests conducted.

Several areas in Scuffletown Creek (east of the Interstate 464 bridge) and Scotts Creek (southern arms of the creek) were very shallow and could not be accessed with large work vessels. The area east of the Interstate 464 bridge in Scuffletown Creek could only be sampled from a small jon boat due to the presence of a low bridge and shallow water conditions. Future sampling in these areas will require an alternative work platform to facilitate maneuvering vibracoring and other sampling equipment around the creek.

Updated bathymetry data for each of the four proposed remediation areas may be useful for planning future sampling and remediation efforts. Updated bathymetry data would prevent the

placement of target stations in areas that are located onshore and would also allow for early identification of areas with potential access problems (i.e., areas too shallow to access by boat). In addition, updated bathymetry data may be used to identify erosional and depositional areas that could affect future remediation efforts.

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ATTACHMENT D

PHASE II SEDIMENT INVESTIGATIONS AND TREATABILITY STUDY

US Army Corps of Engineers
Norfolk District

DRAFT PHASE II SEDIMENT INVESTIGATION REPORT

Scuffletown Creek
Elizabeth River Environmental Restoration

MARCH 2001

Prepared by:

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1.0 INTRODUCTION

1.1 INTRODUCTION AND PROJECT SCOPE

The U.S. Army Corps of Engineers (USACE), Norfolk District (Norfolk District USACE), under Contract No. DACA01-96-D-0021, Task Order No. 0021, between U.S. Army Corps of Engineers, Mobile District and Foster Wheeler Environmental Corporation (Foster Wheeler), tasked Foster Wheeler with conducting a Phase II Sediment Investigation (SI) and Feasibility Investigation (FI) at Scuffletown Creek, Chesapeake, Virginia. The purpose of these studies was to determine the vertical extent of sediment contamination within predetermined "hot spot" locations in Scuffletown Creek, and to develop and examine feasible options for the remediation of the impacted sediments at the site.

1.1.1 Site Location

Scuffletown Creek is a tributary to the Southern Branch of the Elizabeth River located in the city of Chesapeake, VA (Figure 1-1). The creek is located on the east bank of the Elizabeth River, approximately 2 nautical miles from the Eastern and Southern Branch confluence. The Scuffletown Creek study area is bordered by the head of the creek at Bainbridge Boulevard in Chesapeake, and the eastern edge of the Federal navigation channel in the Southern Branch of the Elizabeth River (Figure 1-2). Water depths range from 1 to 10 feet mean lower low water.

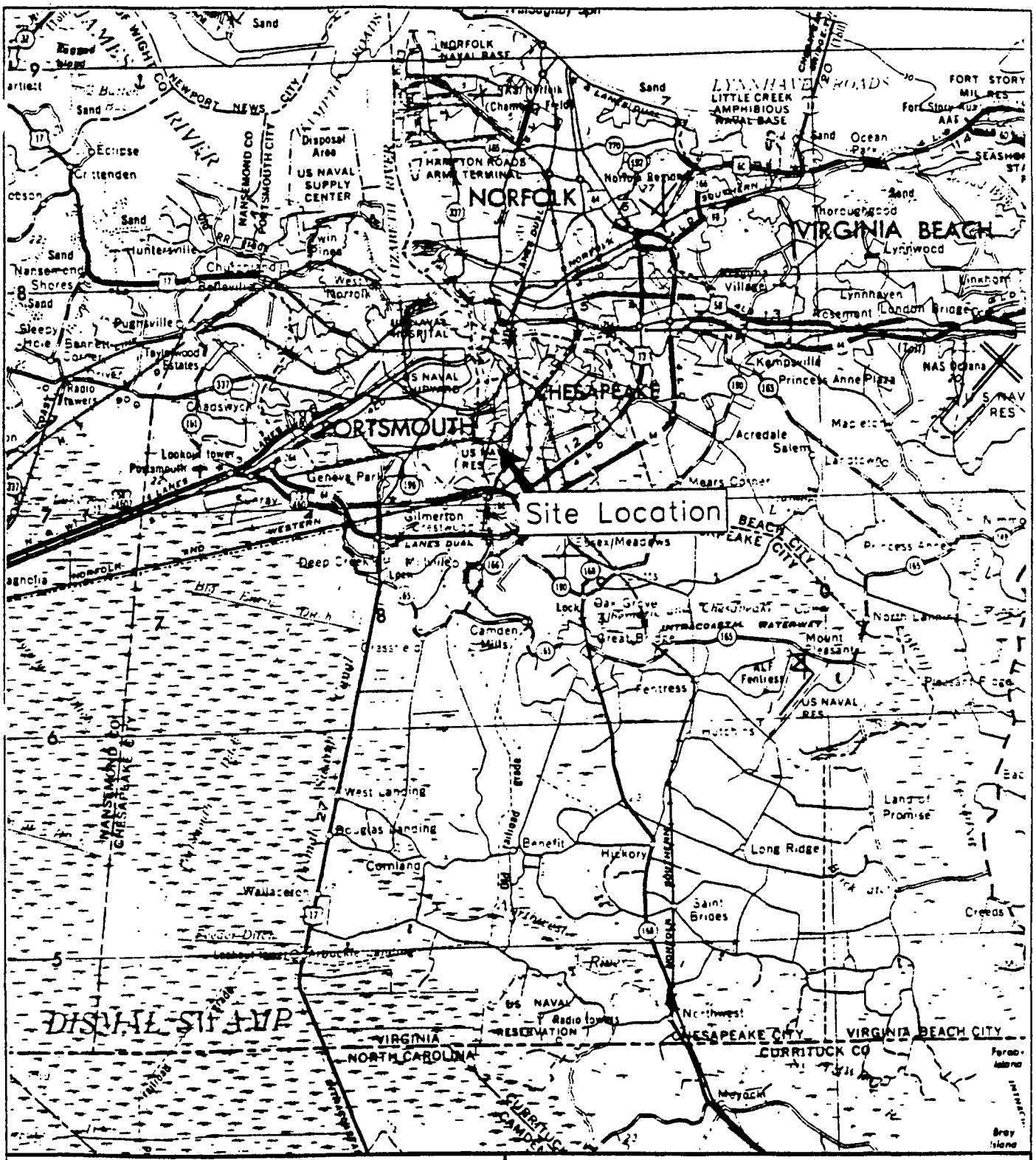
1.1.2 Project Objectives and Scope

Elizabeth River Restoration Project

The Elizabeth River, located approximately 95 miles southeast of Richmond, VA at the junction of Hampton Roads and the Chesapeake Bay, is a tidal estuary that runs through the cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach, draining into the Chesapeake Bay. The river provides navigable waters for commercial, industrial, recreational, and defense use, and is thus the economic mainstay of the Hampton Roads community. The Elizabeth River watershed consists of approximately 300 square miles, of which approximately 145 square miles is tidally influenced.

Potential environmental concerns have arisen within the river basin as a result of increased population and economic growth along the Elizabeth River. The Norfolk District USACE and other entities have prepared numerous reports and studies addressing various aspects of environmental conditions within the Elizabeth River Basin. Some studies have shown that stormwater runoff, point source discharges, and spills from commercial, industrial, and military sources have degraded water quality and adversely impacted river sediments. A comprehensive list of previous studies and investigations is available in the July 1998 *Project Study Plan (PSP) for the Elizabeth River Environmental Restoration-Feasibility Investigation* prepared by the Norfolk District USACE.

The Norfolk District USACE, the Commonwealth of Virginia, the cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach, the Elizabeth River Project (ERP), and the Hampton Roads



Source: U.S.G.S. Topographic Maps (1x2 Degree Series)
Norfolk, Virginia; North Carolina

U. S. Army Corps of Engineers
Norfolk District

Scuffletown Creek
Phase II Sediment Investigation

Figure 1-1
Site Location Map

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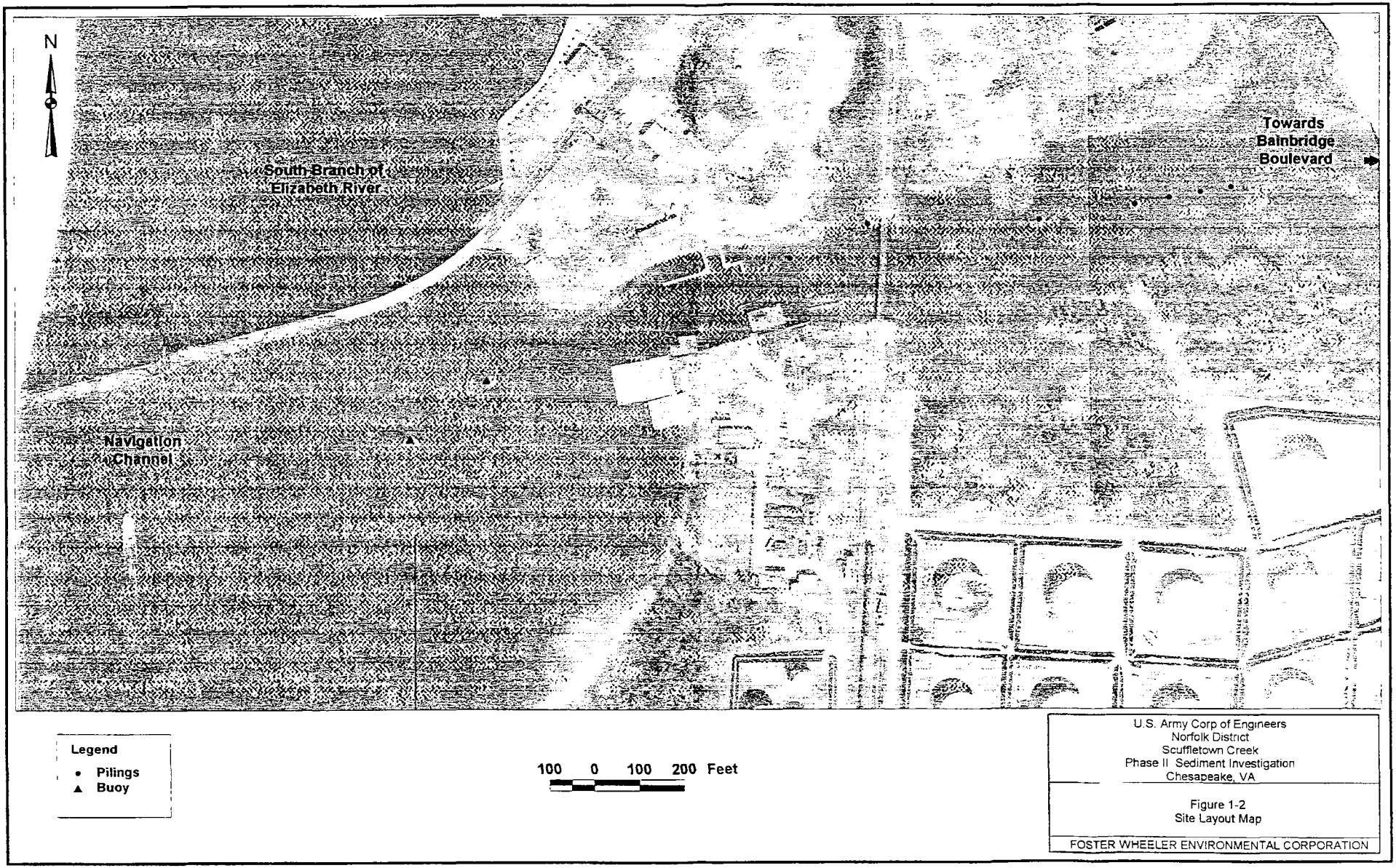
Siteloc.dwg


N
South Branch of
Elizabeth River
Towards
Bainbridge
Boulevard
Navigation
Channel
Legend
Pilings
Buoy
100 0 100 200 Feet
U.S. Army Corp of Engineers
Norfolk District
Scuffletown Creek
Phase II Sediment Investigation
Chesapeake, VA
Figure 1-2
Site Layout Map
FOSTER WHEELER ENVIRONMENTAL CORPORATION

Planning District Commission (HRPDC) have entered into a Feasibility Cost Sharing Agreement (FCSA) to implement a Feasibility Study (FS) for the environmental restoration of sediment and wetlands within the Elizabeth River Basin.

The FS represents the second phase of the two-phase USACE process consisting of the Reconnaissance and Feasibility phases. In support of the FCSA, the Norfolk District USACE, along with the other sponsors, prepared the July 1998 *PSP*. This study is a joint stakeholder document representing the interests of all parties involved in the ERP. It details the work scope, schedule, and budget for the FS. The importance of the FS cannot be overemphasized, as it will serve as the basis for formulating projects and developing a decision-making document to determine whether projects should proceed to construction. The FS is anticipated to strongly consider habitat restoration, which may include sediment remediation as well as wetlands restoration, as a viable alternative to allowing loss of wetlands and degradation of sediments to continue unabated within the Elizabeth River Basin.

A Steering Committee, composed of representatives from USACE and other non-federal sponsors, selected the following four sites to be evaluated for sediment remediation under the FS:

- *Scuffletown Creek.* This site is bordered by the head of the creek at Bainbridge Boulevard in Chesapeake, VA, and the eastern edge of the Federal Navigation Channel in the Southern Branch of the Elizabeth River.
- *Scotts Creek.* This site consists of the entire creek with branches extending to Booker Street, London Boulevard, Leckie Street, and Harrell Street in Portsmouth.
- *East of Campostella Bridge.* This site is bordered by the east side of Campostella Bridge and the western edge of the mouth of Steamboat Creek in Norfolk. This site includes the small cove adjacent to the Campostella Heights neighborhood in Norfolk.
- *Adjacent to the Prior Eppinger and Russel Site.* This site is located offshore to the current Amerada Hess property on the Southern Branch of the Elizabeth River. It is located directly past Freeman Avenue in Chesapeake. The site area is bounded to the west by the eastern edge of the Federal navigation channel.

Foster Wheeler's Support Role

On behalf of the Norfolk District USACE, Foster Wheeler completed a Phase II Sediment Investigation (SI) and Feasibility Investigation (FI) for the Scuffletown Creek Site. The SI constitutes a biased investigation intended to characterize the vertical extents of potential contaminants of concern within the Scuffletown Creek basin "hot spots." After compiling and evaluating all Phase I and Phase II sediment contamination data, Foster Wheeler then conducted a Feasibility Investigation (FI) to identify viable methods for treating contaminated sediment present in Scuffletown Creek.

Of the four "hot spot" sites in the Elizabeth River, the Norfolk District USACE designated the Southern Branch's Scuffletown Creek as the highest priority site warranting additional study and

consideration. Scuffletown Creek was chosen as a demonstration site because it is highly visible next to a city park, represents a cross-section of contamination found in Elizabeth River sediments, and has toxicity levels that could be representative of "manageable" remediation costs. "Lessons Learned" in the efforts for Scuffletown Creek may be applied to the remaining three "hot spot" sites within the Elizabeth River system.

Overall, the results of the Phase II SI/FI for Scuffletown Creek sediments identify - and, to some extent, specify - cost-effective clean up technologies for the contaminated sediment. In turn, these findings will allow the Norfolk District USACE to confidently make a recommendation to obtain Congressional allocation for a sediment cleanup effort.

Major project activities include conduct of a Project Kickoff Meeting and Site Reconnaissance, followed by preparation of a Draft and Final Work Plan consisting of a Field Sampling Plan (FSP), Work Management Plan (WMP), and a Site Health and Safety Plan (SHSP) for conducting the following activities:

- Supplemental Sediment Investigation (SSI)
- Remedial Alternative Development and Screening
- Laboratory Bench-Scale Treatability Studies
- Detailed Analysis of Remedial Alternatives
- Preparation of a Draft and Final Phase II Sediment Investigation Report.

Table 1-1 details the tasks included in the Phase II Sediment Investigation.

1.1.3 Project Organization

Foster Wheeler utilized the staff resources depicted in the Project Organization Chart (Figure 1-3) for implementing the SI/FI work activities. This organization draws upon pertinent technical and managerial resources both within Foster Wheeler and the Norfolk District USACE. This organization has provided an integrated Project Team capable not only of meeting the project's technical requirements, but interpreting these findings within the context of the overall Elizabeth River Restoration Project.

Salient features of this Project Organization are presented below.

Norfolk District USACE

Craig Seltzer serves as the Norfolk District USACE's Technical Team Leader for the SI/FI. Mr. Seltzer has been supported by the following individuals within the Norfolk District USACE during the course of this project:

FIGURE 1-3
PROJECT ORGANIZATION
SCUFFLETOWN CREEK - DRAFT PHASE II SEDIMENT INVESTIGATION REPORT
ELIZABETH RIVER RESTORATION PROGRAM

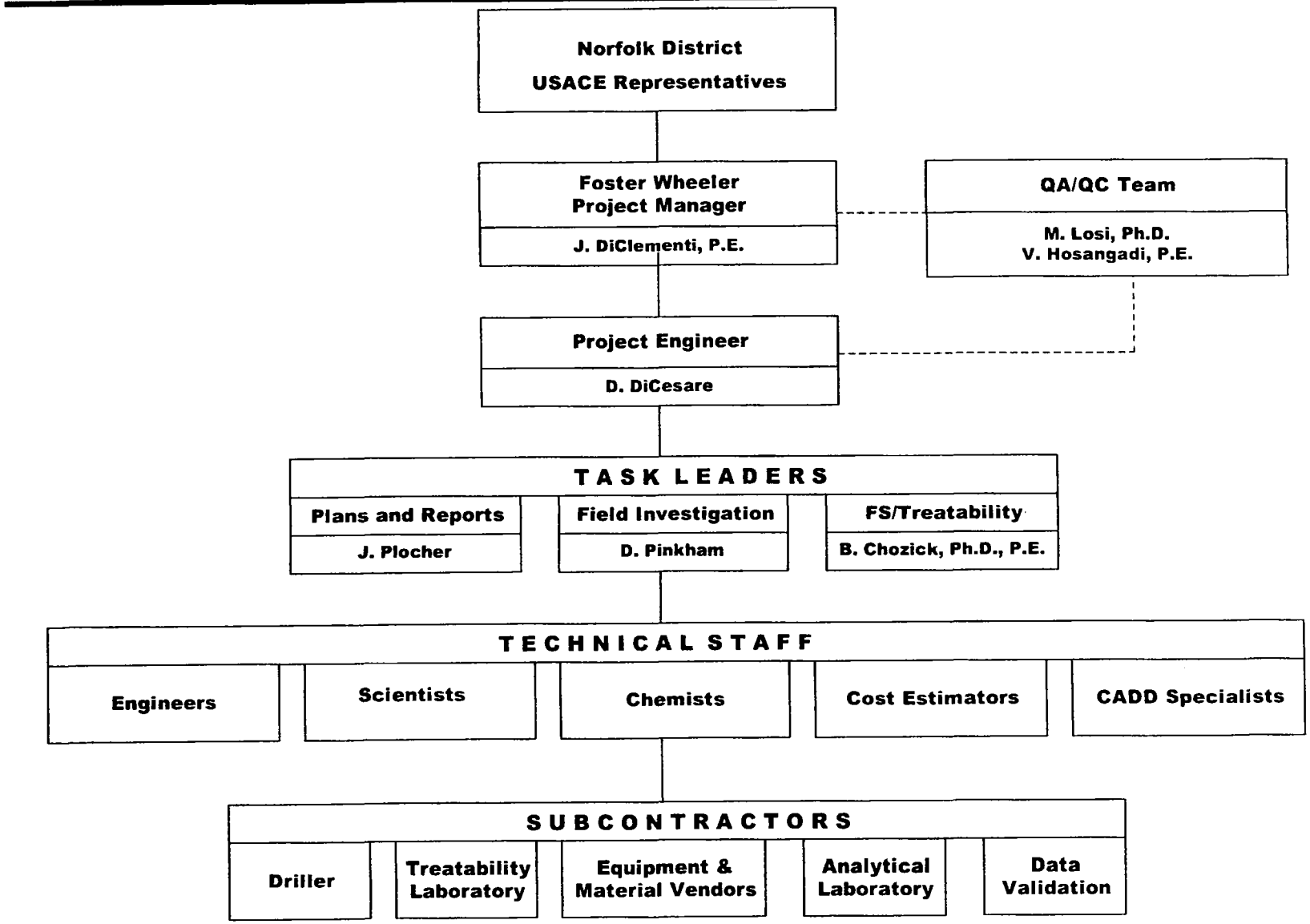


Table 1-1
Tasks Performed for Phase II Sediment Investigation

TASK	NAME OF TASK	DESCRIPTION
Task 1	Project Planning	Gathered and evaluated background information (GIS data and maps); conducted Project Kickoff Meeting and Site Reconnaissance.
Task 2	Project Work Plan and Addenda	Submittal included project description, project objectives, overall technical approach, and schedules.
Task 3	Supplemental Sediment Investigation	Collected 63 sediment samples to determine vertical extent of contamination and further delineate "hot spot" areas.
Task 4	Sample Analysis/Data Validation, Data Assessment and Reporting	Validated, compiled, and analyzed data from Phase I and II investigations, using spreadsheets and GIS mapping.
Task 5	Remedial Alternative Development and Screening	Developed a range of management alternatives to remediate or control the contamination at the four "hot spot" areas. Included literature review and preliminary screening.
Task 6	Treatability Studies	Conducted bench-scale treatability studies to determine the suitability of the retained remedial alternatives, including landfarming/solid phase composting, slurry phase biological treatment, and soil washing.
Task 7	Detailed Analysis of Alternatives	Individually analyzed each alternative against a set of evaluation criteria, and comparatively analyzed alternatives with respect to each other, in order to provide project stakeholders with relevant information to select a site remedy.
Task 8	Phase II Sedimentation Report	Addresses Supplemental Sediment Investigation and Feasibility Study components of the project. Final recommendations as to the feasibility of each remedial alternative are presented.
Task 9	Meetings	Up to two briefings throughout the course of the project are included, in order to enhance information exchange among project stakeholders.

- Mark Gutterman, Geo-Environmental, who serves as the Technical Lead for both the investigation and technology components of the project. Mr. Gutterman succeeded Mr. David Kang, who provided input during the planning phase of the SI/FI project.
- In addition, Mr. Stephen Powell, P.E., Waterways and Ports, has been available to this project as needed to address matters pertaining specifically to sediment dredging.

Foster Wheeler Environmental Corporation

James N. DiClementi, P.E., serves as Foster Wheeler's Project Manager and main Point-of-Contact with the Norfolk District USACE for all aspects of this project. Mr. DiClementi has more than 20 years of environmental engineering and management experience, predominantly involving clients and projects in the Commonwealth of Virginia. Earlier in his career, Mr. DiClementi successfully implemented the design, construction, and operation of a Biotreatment Land Farm facility at the Craney Island Fuel Terminal in Portsmouth, Virginia. In addition, he launched and directed the Tabbs Creek Remediation for NASA Langley Research Center, Hampton, Virginia, which was a complex waterway and wetland cleanup and restoration program.

Mr. DiClementi has been supported in this project by a well-qualified group of environmental scientists and engineers:

- David DiCesare, Biochemical Engineer, who serves as the Project Engineer for all major components of the study;
- Julia Plocher, Civil Engineer, who serves as the Plans and Reports Task Leader;
- Derek Pinkham, Geologist, who served as the Field Operations Leader (FOL) for the Phase II Sediment Investigation; and
- Robert Chozick, Ph.D. Bioengineer, who has focused on the Feasibility Investigation/Treatability Study components of the project.

In addition, a Quality Assurance/Quality Control (QA/QC) Team has been providing senior-level expertise to the Project Team at critical stages of the project. This QA/QC Team consists of Mark Losi, Ph.D. Microbiologist, who specializes in the testing and design of biotreatment systems for a wide range of contaminants; and Vitthal Hosangadi, P.E., Civil Engineer, who has experience in a wide range of remediation technologies and projects.

Dr. Losi and Mr. Hosangadi have provided senior oversight to the Project Team on sediment characterization parameters, technology screening and evaluation process and results, treatability test design and results, and specification and costing of remedial alternatives.

As shown earlier in Figure 1-3, under the direction of the Task Leaders and Project Engineer, a multi-disciplinary technical staff consisting of engineers, scientists, chemists, cost estimators, and AutoCAD specialists has been available to perform specific technical activities.

Subcontractors

Foster Wheeler has utilized several specialty subcontractors to implement specific aspects of this project, including:

- Drilling Firm (EEA, Inc.), to obtain sediment cores from predetermined locations in Scuffletown Creek;
- Treatability Laboratory (HydroQual, Inc.), to perform bench-scale treatability technology studies;
- Analytical Laboratory (Severn Trent Laboratories), a USACE Missouri River Division (MRD) validated laboratory, for performing the analytical testing requirements for the SI, as well as the bulk sediment material subjected to Treatability Testing;
- Data Validation Firm (Meridian Science and Technology, Inc.), to perform various EPA data validation for the SI data set; and
- Various Equipment and Material Suppliers, for items such as personal protection equipment (PPE) and sampling equipment.

1.1.4 Project Schedule

Thus far, the SI/FI Project Schedule has been affected by various factors, primarily subcontractor delays. The schedule provided the Norfolk District USACE with one-week review periods for each project deliverable. In the instances that the schedule needed to be modified, Foster Wheeler contacted the Norfolk District USACE for approval of a revised schedule. A schedule status summary of revised project milestones submittal of the Detailed Analysis of Alternatives is presented in Appendix F.

1.2 SITE BACKGROUND

1.2.1 Site History

Scuffletown Creek is a tributary to the Southern Branch of the Elizabeth River. Adjacent to the area of interest for this project are several properties which may have impacted the sediment. In addition, a large abandoned ship is present near the southern side mouth of the creek adjacent to the ship repair facility. On the west of the creek bank, there are two former creosote plants that were operated in the 1920s, Wycoff Pipe & Creosote and Atlantic Wood Industries. Wycoff Pipe and Creosote is adjacent to property owned by the Portsmouth Port and Industrial Commission. At this site, there is a high probability of Polynuclear Aromatic Hydrocarbons (PAH) contamination from the former creosote activities. Atlantic Wood is a Superfund Site that has been under federally-mandated remedial action. Previous studies in the vicinity of the Atlantic Wood site indicated Pentachlorophenol (PCP), PAHs, heavy metal, and dioxin/furan contamination. In addition to contamination from creosote facilities, there may be contaminants from leachate and stormwater runoff from a dumping area east of the Elizabeth River Park.

1.2.2 Geologic Setting

The study area is situated within the Atlantic Coastal Plain Physiographic Province, which is characterized by flat to gently rolling terrain and generally low elevations that decrease gradually in a easterly direction. The line of demarcation (fall line) between the Atlantic Coastal Plain and the adjacent Piedmont Physiographic provinces bisects Virginia in a southerly direction. The Virginia Coastal Plain, which lies east of the fall line, in underlain by a wedge of sedimentary rocks that have been deposited during periods of elevated sea level. These sediments rest on an eroded surface of Precambrian to early Mesozoic basement rock. Two-thirds of this wedge is comprised of late Jurassic and Cretaceous clay, sand and gravel. These material were eroded from the Appalachian mountains, carried eastward by rivers and deposited in deltas in the newly formed Atlantic Ocean basin. A sequence of thin, fossiliferous marine sands of Tertiary age overlie the older strata. They were deposited in warm shallow seas during repeated marine transgressions across the Coastal Plain. This pattern of deposition was interrupted about 35 million years ago by a large meteorite that plummeted into a shallow sea, and created a crater more than 90 km in diameter. This crater was subsequently buried under about 1.2 km of younger sediment. Lastly, Tertiary and Quaternary sand, silt and clay, which cover most of the coastal plain, were deposited during interglacial highstands of the sea under conditions similar to those that exist in the modern Chesapeake Bay and its tidal tributaries.

1.2.3 Previous Investigations

Numerous studies of the Elizabeth River have been conducted to document regional sediment quality, impacts to aquatic biota, loss of wetlands, and potential remediation alternatives. Some of the significant findings relating to aquatic impacts and contaminants of concern are highlighted below.

The *Bulletin of Environmental Contamination and Toxicology* (Roberts, et al, 1989) indicated with aquatic toxicity tests that bottom sediments from creosote-contaminated areas are highly toxic to resident fish species. The *Marine Pollution Bulletin* (Dauer 1993), which involved studies in the Southern Branch of the Elizabeth River, classified the benthic communities as highly stressed. The *Elizabeth River Long-term Monitoring/Management Program – Phase II* (Alden and Winfield 1993) identified bioaccumulation of contaminants and mutagenic chemicals in blue crab tissue as a threat to human health. The *Elizabeth River Environmental Restoration Study* conducted by the Norfolk District USACE (1997) identified high concentrations of organic and inorganic chemical pollutants that have adversely impacted aquatic life in the Elizabeth River. Health problems in finfish were documented in the river.

Several additional reports have been prepared documenting contaminant conditions present in the Elizabeth River. Heavy metals and PAHs were identified as the primary contaminants of concern in the river during the study *Defining the Problem: The Elizabeth River, a Region of Concern* (Alden and Winfield 1995). In addition, pentachlorophenol, tributyl tin, phthalates, polychlorinated biphenyls (PCBs), and other priority pollutants were reported to be present in the river in the *Feasibility Study to Mitigate Existing Contaminated Subaqueous Sediments in the Southern Branch* (Canonizado, et al., 1996).

During the Phase I Sediment Investigation (EA 1999), semi-volatile organic compounds (SVOCs) and priority pollutant metals were determined to be present in the Scuffletown Creek area of investigation, at concentrations that exceed marine sediment quality guidelines (these criteria included Effects-Range Low, Effects-Range Median, Threshold Effects Limit, and Probable Effects Limit). These compounds were detected in eight distinct "hot-spot" locations throughout the site. These hot-spot locations have formed the basis for the Phase II sediment investigation. For the purposes of the Phase II sediment investigation, the Norfolk District USACE and Foster Wheeler consolidated these eight areas into four areas (see Section 2.2 and Figure 2-1).

2.0 SCOPE OF WORK OVERVIEW

2.1 PROJECT PLANNING (TASKS 1 AND 2)

The project planning phase involved gathering and evaluating background information from USACE personnel, including GIS data/maps on hot spots and survey information. The focal point of this phase was the Project Kickoff Meeting and Site Reconnaissance, involving key Norfolk District USACE and Foster Wheeler personnel, conducted on April 11, 2000. The "Kickoff Meeting Overview and Trip Report" is presented as Appendix A.

Development of the Project Work Plan was the next phase in the project planning process. The Project Work Plan was submitted in June 2000. Review comments from the Norfolk District USACE, the Virginia Institute of Marine Science, and the Virginia Department of Environmental Quality were submitted to Foster Wheeler. Foster Wheeler prepared a response to comments that also represented the finalization of the Project Work Plan.

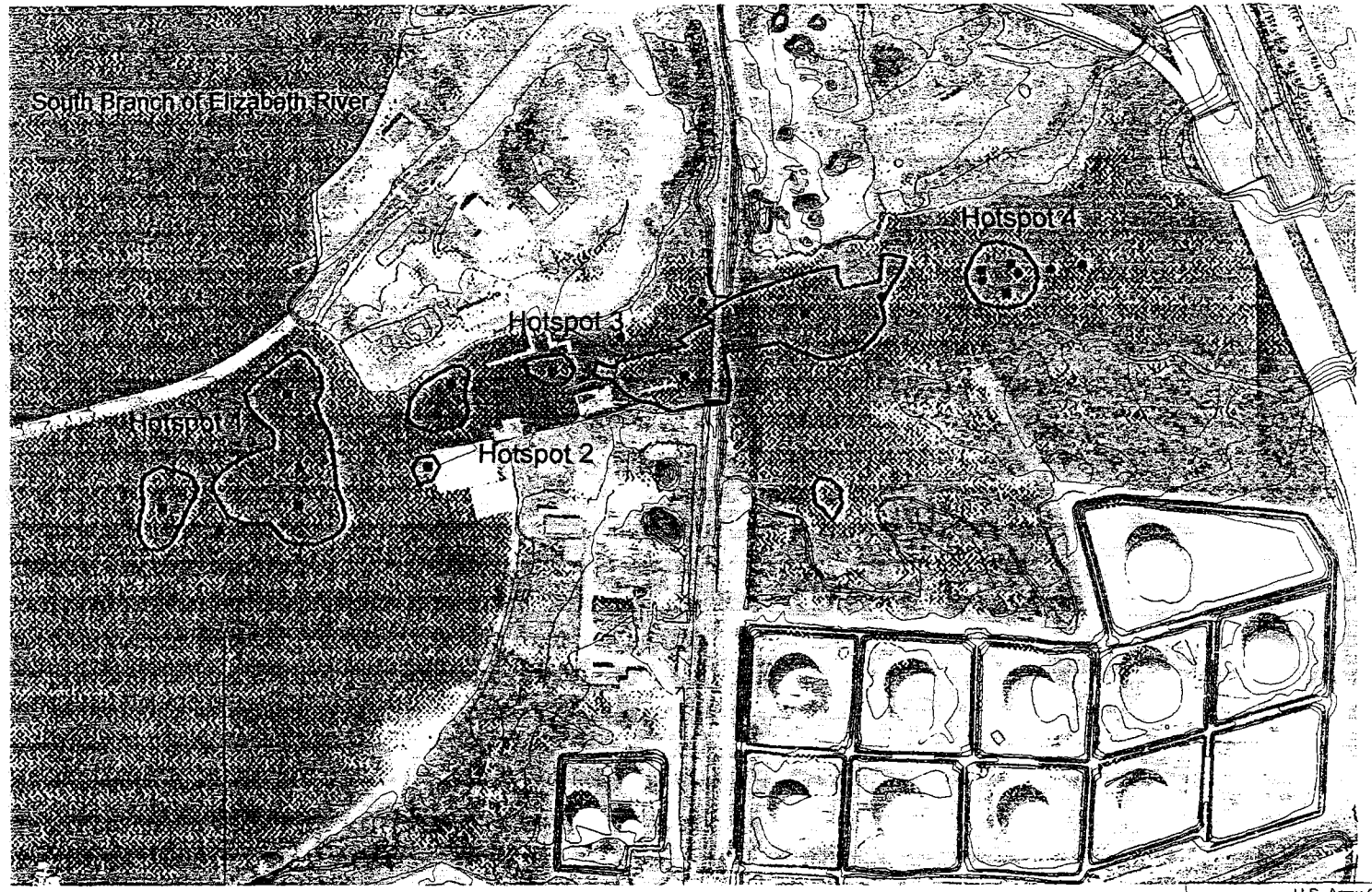
2.2 SUPPLEMENTAL SEDIMENT INVESTIGATION (TASK 3)

The objective of the supplemental sediment investigation was to determine the vertical extent of the environmental impact that was detailed in the Phase I Sediment Investigation Report. Specifically, eight hot spot areas of sediment contamination were identified to a depth of no more than two feet below surface grade. Hot spot locations identified in the Phase I Sediment Investigation Report are shown in Figure 2-1. The Norfolk District USACE consolidated the eight hot spot locations into four hot spot areas for the purposes of further investigation. Approximately five days of drilling/sampling, conducted during the week of July 31, 2000, were required to complete the Phase II Sediment Investigation.

A summary of parameters, analytical methods, containers, and the number of samples per phase is provided in Table 2-1. The methodologies proposed to complete the investigative field activities are described in detail in Appendix B, including vibra-core sediment sampling and sample packaging and shipping.

Samples were collected with decontaminated sampling equipment and placed in new, clean sample containers. All samples were packed on ice in a portable cooler immediately following containerization, to maintain a temperature of 4° C. As detailed in Appendix B, chain-of-custody protocol was maintained to provide a record of samples collected and shipped, as well as to document custody transfer of the samples from collection to analysis.

Samples were shipped via overnight carrier directly to Severn Trent Laboratories, the selected USACE Missouri River District (MRD) validated laboratory. Samples were analyzed with standard turn-around times of 21 days from receipt of samples at the lab for hard-copy reports.



- Proposed Sediment Sample Location
- Buoy
- Pilings
- Hot Spot Areas Identified in Previous Investigations
- Topographic Contours

200 0 200 400 Feet

U.S. Army Corp of Engineers
Norfolk District
Scuffletown Creek
Phase II Sediment Investigation
Chesapeake, VA

Figure 2-1
Proposed Sediment Sample and Hot Spot Location Map

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TABLE 2-1
SCUFFLETOWN CREEK - PHASE II SEDIMENT INVESTIGATION/FEASIBILITY INVESTIGATION
ANALYTICAL SUMMARY FOR CONTAMINATION ASSESSMENT

Parameters	No. of Samples	Field Duplicates[1]	Rinsate Blanks [2]	Total Samples	Method	Sample Container [3]	Holding Time [4]
Sediment							
CONTAMINATION ASSESSMENT							
Semi-Volatile Organics	63	4	5	72	SW3540A/8270C	4 oz glass	7 days/40 days 28 days
Priority Pollutant Metals	63	4	5	72	SW3010/6010/7000	8 oz glass	6 months (Hg 28 days)
Total Organic Carbon	63	4	5	72	SW 9060	4 oz glass	ASAP
Soil Grain Size Analysis	63	4	5	72	ASTM D422	4 oz glass	None

Note: All samples are cooled to 4°C.

1 Duplicates collected 1/20 samples each parameter.
2 Field blanks collected 1/10 samples.
3 Several parameters may be determined from same sample jar.
4 Maximum time from collection to analysis, or to extraction/analysis.

2.2.1 Number and Location of Samples

A total of 63 sediment samples were collected from three locations in each of the four hot spot areas in Scuffletown Creek, for a total of 12 sampling locations. At each station, sediment samples were collected from the surface sediment (0-2 feet), 2-3 feet, 3 to 4 feet, 4 to 5 feet, and 5 to 6 feet intervals. Approximate sample locations are presented in Figure 2-1. Sample locations were located using a semi-spatial determination method. At the site, the subcontracted driller used a Global Positioning System (GPS) to provide sample locations with a horizontal accuracy of $\pm$5 meters.

Sediment samples were analyzed for Semi-Volatile Organics Analysis (EPA Method 8270C), Priority Pollutant Metals (EPA Method 6010B), Total Organic Carbon (EPA Method 9060), Particle Size Analysis of Soils (ASTM Method D422), Total Kjeldahl Nitrogen (EPA Method 351), Nitrate/Nitrite (EPA Method 353), Ammonia (EPA Method 350), Biochemical Oxygen Demand (EPA Method 405), Phosphate (EPA Method 365), Chemical Oxygen Demand (EPA Method 410), and Total Plate Count.

As sufficient sediment was not always present in the initial sediment sample, multiple sediment samples may have been taken from specific locations. Prior to transferring the sediment to the sample container, the sediment was homogenized/composited utilizing the method described in Appendix B.

2.2.2 Quality Control Samples

Quality control (QC) samples were collected and analyzed in order to assess the precision, accuracy, reproducibility, and completeness of each sample result, in addition to assessing overall data quality. Specifically, four QC field duplicate samples and five QC equipment rinsate blanks were collected and analyzed for the following: SVOAs, PP Metals, and TOC.

2.2.3 Investigative Derived Material

Investigative derived material (IDM) generated during field investigation activities included:

- Excess sediment derived from soil borings,
- Decontamination fluids, and
- Used PPE.

In accordance with the Norfolk District USACE's specifications, excess sediment collected during the sediment investigation was placed directly back into the creek.

A minimal volume of decontamination fluids was generated during this environmental investigation. All potable water, phosphate-free detergent, and deionized water rinsate fluids generated during sampling equipment decontamination was discharged directly into Scuffletown Creek. All nitric acid and isopropanol fluids generated during decontamination was placed into

appropriate containers, labeled, and given to the Norfolk District USACE for final handling and disposition.

Used personal protective equipment was disposed of as general refuse.

2.2.4 Health and Safety Management

During the field event for the supplemental sediment investigation, there were no occurrences of health and safety-related incidents. A Site Health and Safety Plan was prepared and was presented as an Addendum to the Project Work Plan (June 2000).

2.2.5 Media Event

During the field event of the Supplemental Sediment Investigation, representatives of the Norfolk area NBC affiliate news station were present to film a segment to air on the news program that evening. Foster Wheeler coordinated all aspects of this media event with the Norfolk District USACE's Public Affairs Office. The newscaster was given a brief history of the site and surrounding area, as well as an overview of the Elizabeth River Restoration Project. Footage was taken of the area at the mouth of the creek extending out into the Elizabeth River. The newscaster interviewed key personnel of the Norfolk District USACE, Foster Wheeler, and the drilling subcontractor (EEA, Inc.). The segment that was aired presented an extremely positive and well-received perspective of this particular aspect of the Elizabeth River Restoration Project.

2.2.6 Data Management (Task 4)

2.2.6.1 Data Reduction

Data collected during the Phase I Sediment Investigation and data from the Supplemental Sediment Investigation were assembled, reviewed, and evaluated. The data collected to characterize the site were organized into spreadsheets and analyzed to identify the horizontal and vertical extent of contamination.

Sediment quality data from the previous sampling program and from this Phase II investigation were evaluated and mapped to illustrate the extent of contaminants detected. Where inconsistencies were observed, field and laboratory procedures, the passage of time, and other factors were evaluated to account for the differences. The results of the evaluation were discussed in the Interim Data Report (under Task 4).

2.2.6.2 Data Validation

Foster Wheeler procured a subcontractor (Meridian Science and Technology, Inc.) to perform data validation of the laboratory analytical results. This validation constituted an independent appraisal of Quality Assurance/Quality Control (QA/QC) results provided by the contract analytical laboratory. Data validation was performed in accordance with the following EPA guidance documents:

- Region III Modifications to the National Functional Guidelines for Organic Data Review (EPA, September 1994).
- Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analysis (EPA, April 1993).
- Innovative Approaches to Data Validation (EPA Region III, 1995).

All organic analytical data were reviewed at a level equivalent to the M-3 level of data validation. All inorganic data were reviewed at a level equivalent to the IM-2 level of data validation.

2.3 REMEDIAL ALTERNATIVE DEVELOPMENT AND SCREENING (TASK 5)

The activities performed under Task 5-Remedial Alternative Development and Screening constituted the first of a series of steps in the Feasibility Investigation (FI) for treatment of Scuffletown Creek contaminated sediment. The FI consisted of the following components: Remedial Alternative Development and Screening (Task 5), Treatability Studies (Task 6), and Detailed Analysis of Alternatives (Task 7).

2.3.1 Remedial Alternative Development

Under Task 5, Foster Wheeler developed a range of distinct management alternatives to remediate or control the contamination in the four consolidated "hot spot" areas of concern at Scuffletown Creek.

Alternatives for remediation were developed by assembling combinations of technologies into alternatives that addressed the sediment contamination on an area-wide basis. In conjunction with the Norfolk District USACE, Foster Wheeler followed a step-wise process, described below, to develop these remedial alternatives:

- Establishing remedial action objectives for removal and treatment of contaminated sediment based on factors such as contaminant-specific standards or regulatory guidelines, risk factors, and treated material end usage.
- Developing general response actions for contaminated sediment "hot spots", including "No Action" (as a comparative baseline); containment of sediment in place (especially for sediment contamination at depth); treatment of sediment in place (or *in-situ* treatment); dredging and containment (e.g., dredging of surface sediment and containment of sediment at depth); and dredging and treatment. The "dredging and treatment" option emphasized on-site treatment alternatives (e.g., biological treatment by landfarming).
- Estimating volumes of "hot spots" (i.e., remedial take-offs) to which general response actions might be applied.
- Identifying and evaluating the technologies applicable to each general response action, in an attempt to eliminate those that cannot be implemented technically at the site.

- Identifying and evaluating technology process options, specifically process options for each technology type being retained for consideration.

A comprehensive review of technical literature was used to identify all recent technological developments and applications for treatment of contaminated soils and sediments. This literature review, focusing specifically on treatment of semi-volatile organic compounds and metals found in Scuffletown Creek sediment, pertained to the last two steps of remedial alternative development defined above. Remedial alternative development culminated in the compilation of a list of appropriate technologies and process options for the treatment or control of those compounds present in the Scuffletown Creek sediment.

2.3.2 Remedial Alternative Screening

Foster Wheeler refined and screened the remedial alternatives to reduce the number of alternatives to be evaluated in detail. The screening focused on the treatment and restoration components of the remedial alternative. The Norfolk District USACE has specified the methods by which contaminated sediment will be dredged from the creek. Foster Wheeler analyzed the remedial alternatives to evaluate and develop control measures for potential "side effects" of treatment systems (e.g., air emissions, water discharges).

The treatment components of each remedial alternative were examined for their ability to effectively reduce media-specific or area-wide risk potential. For each remedial alternative, the level of treatment that must be applied to meet the material's planned end use was considered so that possible human health or environmental impacts are minimized. Planned end uses of treated sediment includes pre-treatment for land disposal, full treatment for clean backfill material, or other final disposition plans.

In order to highlight the most promising alternatives, Foster Wheeler evaluated remedial alternatives on a general basis with respect to their *effectiveness, implementability*, and *cost* in order to highlight the most promising alternatives. This evaluation placed greater emphasis on long-term aspects of the remedial alternative, as opposed to short-term impacts associated with construction and start-up.

Effectiveness of an alternative was assessed primarily based on the long-term level of ecological protection provided to the creek. For example, does the alternative serve to permanently reduce toxicity, mobility, or volume of the contaminated material?

The *Implementability* screening examined both the technical and administrative feasibility of construction, operating, and maintaining a remedial alternative. Here, the "technical feasibility" refers to the ability to construct and operate the system in accordance with all program goals and technology-specific regulations. "Administrative feasibility" refers to the ability to obtain all necessary operating permits or agency approvals; utilize local facilities, equipment, materials, and manpower; or other factors.

The *Cost* evaluation attempted to reduce the uncertainties associated with cost parameters or elements, such as cost estimation guides, vendor pricing, or cost curves. Prior estimates, site-

cost experience, and sound engineering judgement were applied to reduce uncertainty associated with comparative cost analysis.

2.4 TREATABILITY STUDIES (TASK 6)

Upon completion of the Remedial Alternative Development and Screening (Task 5) and receipt of concurrence from the Norfolk District USACE, Foster Wheeler conducted bench-scale treatability studies under Task 6 to determine the suitability of the retained remedial alternatives. Treatability studies were performed for those alternatives and technologies that require site-specific and/or contaminant-specific evaluations (e.g., biological treatment). Work elements under Task 6 included Test Plan Preparation, Sediment Sample Collection, Treatability Studies, and Data Compilation and Evaluation. Reports associated with the treatability studies were prepared under Task 8-Phase II Sediment Investigation Report.

2.4.1 Test Plan Preparation

Prior to conducting treatability studies, and after collecting pertinent input from the Norfolk District USACE, Foster Wheeler developed a Test Plan. This Test Plan constituted a detailed supplement to the Project Work Plan focused specifically on the conduct of Treatability Studies. The Test Plan addressed the following components of the studies:

- Technologies that were studied;
- Types and goals of the studies;
- Specific vendor procedures, facilities, methodologies, and equipment that were utilized in the conduct of the studies;
- Data management and evaluation procedures;
- Schedule for completing the studies; and
- Reporting formats and procedures that were followed.

Vendor procurement arrangements were finalized after the Norfolk District USACE approved the Test Plan.

2.4.2 Sediment Sample Collection

Due to unavoidable delays in driller availability, samples of sediment for use in the Treatability Studies were collected during a separate (and earlier) field effort from the Phase II Sediment Investigation field effort. Bulk sediment material was collected from various locations in Scuffletown Creek on July 13, 2000. Parameters pertaining to the collection of treatability samples include location, volume requirements, field collection method, and sample processing methods, as summarized in Table 2-2.

TABLE 2-2
SCUFFLETOWN CREEK - PHASE II SEDIMENT INVESTIGATION/FEASIBILITY INVESTIGATION
ANALYTICAL SUMMARY FOR TREATABILITY CHARACTERISTICS

Parameters	No. of Samples [1]	Field Duplicates	Rinsate Blanks	Total Samples	Method	Sample Container [2]	Holding Time [3]
Sediment							
TREATABILITY CHARACTERISTICS							
Total Kjeldahl Nitrogen	2	0	0	2	EPA 351	4 oz glass	None
Phosphate	2	0	0	2	EPA 365	4 oz glass	None
Nitrite/Nitrate	2	0	0	2	EPA 353	4 oz glass	None
Ammonia	2	0	0	2	EPA 350	4 oz glass	None
Chemical Oxygen Demand	2	0	0	2	EPA 410	4 oz glass	None
Biochemical Oxygen Demand	2	0	0	2	EPA 405	4 oz glass	None
Total Plate Count	2	0	0	2	--	4 oz glass	None
Semi-Volatile Organics	2	0	0	2	SW3540A/8270C	4 oz glass	7 days/40 days 28 days
TCLP Metals	2	0	0	2	SW3010/6010/7000	8 oz glass	6 months
Pesticides/PCBs	2	0	0	2	SW8081/8082	4 oz glass	14 days/40 days

Note: All samples are cooled to 4°C.

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1 For "Treatability Characteristics" samples, one sample was collected from 5 CF (or 30-gallon container) of "average" contaminant characteristic sediment and a second sample was collected from 5 CF (or 30-gallon container) of "maximum" contaminant characteristic sediment

2 Several parameters may be determined from same sample jar

3 Maximum time from collection to analysis, or to extraction/analysis

Sample Locations
Two sediment samples representing either the average or the maximum contaminant characteristics were studied for each technology. Since the extent of biodegradation can be affected by contaminant levels, both sampling scenarios were maintained for each technology type. Based on evaluation of the Phase I Sediment Investigation contamination profiles, Foster Wheeler selected two optimum sample locations from within the "Hot Spot" areas. In each of these two designated sample locations, sufficient sediment volume was collected and placed into appropriate containers for shipment to the treatability laboratory.

Volume Requirements
Across all four of the candidate technologies, 10 cubic feet (CF) of sediment (or approximately two 30-gallon containers) were required for conducting the entire treatability testing sequence. This sequence consisted of test runs for each technology on sediment samples representing both an *average* contaminant characteristic and a *maximum* contaminant characteristic.

Field Collection
For purposes of treatability testing, Foster Wheeler collected dedicated sediment core samples from pre-designated locations in Scuffletown Creek "hot spot" areas. Foster Wheeler collected sediment samples down to maximum depths of approximately 2 feet into the creek basin. All sediment material was placed into one of two 30-gallon drums for shipment to the treatability laboratory: one drum representing the *average* contaminant characteristic and the second drum representing the *maximum* contaminant characteristic.

Sample Processing
Sediment samples remained undisturbed to the maximum extent practicable. Also, the material was not drained nor preserved in any manner. The treatability laboratory refrigerated the sample material upon receipt.

2.4.3 Treatability Studies

Treatability studies were conducted on samples of contaminated sediment from Scuffletown Creek. Two samples representing average and maximum contaminant characteristics were studied for each technology. These samples were analyzed for metals, semi-volatile organic compounds (SVOCs), pesticides/PCBs, and Toxicity Characteristic Leachate Procedure (TCLP) metals. The general approach for each of the candidate technologies is presented below. Note that phytoremediation, which was presented in the Draft Work Plan as a technology to be evaluated, was replaced by soil washing, a physical separation technology. This revision was made after discussion between the Norfolk USACE and Foster Wheeler, regarding a review comment from the Norfolk USACE suggesting inclusion of an extraction remediation technology in the treatability studies. Also, stabilization, which was originally (based on Phase I data) a technology to be evaluated, was eliminated from the treatability study with Norfolk USACE's concurrence. Since TCLP metals, with the exception of a very low lead detection, were below detection levels in the bulk sediment samples, treatment of metals was determined not to be necessary.

2.4.3.1 Landfarming/Solid Phase Composting

Landfarming has been used successfully in the remediation of a variety of contaminants including polynuclear aromatic hydrocarbons. Foster Wheeler successfully applied landfarming methods to petroleum hydrocarbon contaminated soils placed into the Biological Treatment Cell located at the U.S. Navy's Craney Island Fuel Terminal, Portsmouth, Virginia.

Landfarming processes are generally aerobic processes. However, Foster Wheeler investigated both aerobic and anaerobic processes using respirometry. A biological seed acclimated to petroleum hydrocarbons (wood chips and finished compost from a municipal wastewater treatment plant) was used as an inoculum. Two dosages were tested under aerobic and anaerobic conditions for each sample and each flask was run in replicate (16 samples). Nutrients were also added as necessary. The tests were run for 21 days. Oxygen utilization (aerobic) and gas production (anaerobic) was monitored. At the end of the test, one sample from each pair of flasks was analyzed for organics and TCLP metals (eight samples).

2.4.3.2 Slurry Phase Biological

Slurry phase biological treatment generally requires an acclimated biological seed for effective treatment. An acclimated seed can be developed; however, this can require several weeks to develop in the laboratory. These studies were conducted by acquiring an activated sludge seed from Bayway Oil Refinery's wastewater treatment plant in Linden, New Jersey. The seed was added to contaminated sediments to produce a 10 to 15% slurry. The slurry was kept in suspension with mechanical mixing and aeration. Temperature was monitored daily. Oxygen uptake and soluble chemical oxygen demand (COD) were monitored and slurry samples were analyzed twice per week for polynuclear aromatic hydrocarbons (PAHs). The reactors were operated for 28 days in this manner.

2.4.3.3 Soil Washing

Soil washing has been used effectively for remediation of metals and semivolatile organics, including PAH compounds, and is a well-established process historically used in the mining industry. Soil washing supplies mechanical energy and water to liberate contaminants from the surfaces of sediment particles, and separates the more highly contaminated fines from coarser particles to reduce the volume of material requiring further treatment. The fine-grained sediments are treated with doses of polymers or surfactants, and mechanically agitated to liberate contaminants from the soil particles. The study was conducted in an upflow mini-column to promote efficient contact of water and cleansing agents with the sediment. The washwater and washed sediment were analyzed for COD, PAHs, and other parameters. Various agents were tested to evaluate their effectiveness, including hot water, surfactant (two doses of Igepal CA-720, a commercially available non-ionic cleansing agent), and acid.

2.4.4 Data Compilation and Evaluation

Treatability study data were compiled into a series of appropriate tables and graphics. Comparisons were made to test controls and treatment objectives. Conclusions were made with regard to the treatment objectives.

2.5 DETAILED ANALYSIS OF ALTERNATIVES (TASK 7)

Upon completion of the Remedial Alternatives Development and Screening (Task 5) and Treatability Study (Task 6) activities, Foster Wheeler compiled all data and conducted a Detailed Analysis of Alternatives. This Detailed Analysis of Alternatives consisted of two major components:

- *Individual Analysis* of each alternative against a set of evaluation criteria
- *Comparative Analysis* of all options against the evaluation criteria with respect to one another.

Overall, Foster Wheeler considers the Detailed Analysis of Alternatives as the evaluation and presentation process necessary to provide project stakeholders with all relevant information for selection of a site remedy. With the exception of projects being performed under an Administrative Consent Order (e.g., CERCLA or RCRA mandates), the evaluation criteria to which remedial alternatives are compared may be customized to reflect those factors of highest priority to the stakeholders. For the purposes of this Detailed Analysis of Alternatives for the Scuffletown Creek FI, Foster Wheeler evaluated remedial alternatives against the evaluation criteria identified in Table 2-3. These criteria were developed following extensive discussions with Norfolk District USACE's representatives, and are based on specific parameters of the Elizabeth River Restoration Project.

Individual Analysis
The "Individual Analysis" performed under Task 7 consisted of the following elements:

- Technical Description of the alternative, including the overall management strategy;
- Summary Table addressing the performance of each alternative against each evaluation criterion, including:
  - Cost
  - Implementability
  - Effectiveness
  - Compliance with ARARs

Table 2-3
Evaluation Criteria for Detailed Analysis of Alternatives
Scuffletown Creek Contaminated Sediment
(Page 1 of 2)

Evaluation Criterion	*Description*	*Comments*
Cost	Engineering cost estimates were developed for each remedial alternative including Capital, Operation and Maintenance, and Present Worth components. Estimates were developed in accordance with EPA's "Remedial Action Costing Procedures Manual". Vendor-supplied information and in-house cost models were used to develop these "study estimates".	Remedial alternative cost estimates are critical to the remedy selection process and are the basis for obtaining program-level funding for remedial design and construction.
Implementability	This criterion addresses the question of whether (or how) the remedial alternative can be constructed, operated, and maintained in a reliable manner. Important factors include the availability of land, facilities, equipment, materials, or manpower locally; past applications experience with technologies or processes of choice; availability of local disposal facilities for residual waste; tolerance for time commitments required for effective treatment; availability of resources for long-term operation and maintenance requirements; or other factors.	Foster Wheeler attempted to develop less complex treatment systems with well-defined treatment goals/end usage options.
Effectiveness	This criterion addresses the effectiveness of sediment treatment systems.	Critical items to identify are the contaminant levels in the dredged sediment and the level of treatment required to meet the disposal requirements for the chosen final disposition of the treated sediments.
Compliance with ARARs	Norfolk District USACE has established 2-3 times the Effects-Range Median (ERM) value as the standard for sediment removal. Sediment treatment standards must be developed based on factors such as ARARs analysis, planned end use of treated material, and minimum technological standards for treatment units. Chemical-specific, action-specific, and location-specific ARARs were evaluated. The ARARs may be applicable to each of the treatment technologies under consideration.	ARARs analysis reflects Federal, State, and Local requirements and the latest advisories and guidance information. Foster Wheeler's evaluation primarily addresses ARARs for the treatment systems; and, to a lesser extent, the dredging/sediment removal, waste transportation and disposal, and restoration steps.

Table 2-3
Evaluation Criteria for Detailed Analysis of Alternatives
Scuffletown Creek Contaminated Sediment
(Page 2 of 2)

Evaluation Criterion	*Description*	*Comments*
Toxicity, Mobility, or Volume Reduction	This criterion considers the amount of hazardous or toxic constituents which are destroyed or immobilized by the remedial action, as well as the types and quantities of residuals left behind.	Foster Wheeler evaluated this criterion with respect to on-site treatment systems, all of which serve to reduce the toxicity, mobility, or volume of contaminated sediment to some extent.
Acceptance of Project Stakeholders	Elizabeth River Environmental Restoration Stakeholders include Norfolk District USACE, Commonwealth of Virginia, local municipalities, academic institutions, private sponsors, and the local community.	Foster Wheeler's evaluation against this criterion emphasized proactive treatment solutions involving beneficial reuse endpoints.
Protection of the Environment and Human Health	Elizabeth River Environmental Restoration is focused on ecological restoration and enhancement. This criterion addresses permanent risk reduction associated with the remedial alternative.	Foster Wheeler evaluated "Protection of the Environment and Human Health" with regard to on-site treatment system applications.

- Toxicity, Mobility, or Volume Reduction
- Acceptance of Project Stakeholders
- Protection of the Environment and Human Health.

Comparative Analysis

Upon completing the individual analysis, Foster Wheeler compared and contrasted the alternatives with one another, with respect to each of the seven evaluation criteria. This analysis differs from the preceding analysis, in which each alternative was analyzed independently without consideration of interrelationships between alternatives.

After submittal of the detailed analysis, a conference call was held on February 1, 2001, between Norfolk District USACE and Foster Wheeler personnel. Foster Wheeler provided a verbal briefing on the conclusions and recommendations of the detailed analysis, and the Norfolk District USACE communicated review comments and any requests for additional information. This discussion enabled Foster Wheeler to efficiently incorporate client comments and finalize the Detailed Analysis of Alternatives.

3.0 SUMMARY OF PHASE II SEDIMENT CONTAMINATION INVESTIGATION

3.1 SCOPE AND OBJECTIVES

The objective of the Phase II Sediment Contamination Investigation was to provide the Norfolk District USACE with analytical results validated by a third party validating firm (under subcontract to Foster Wheeler), indicating the estimated depth of sediment contamination within predetermined "hot spot" locations in Scuffletown Creek. In addition, this investigation provided some comparison between the results obtained by the Foster Wheeler Phase II investigation and the Phase I Sediment Investigation performed by EA Engineering, Science and Technology, Inc. (EA, 1999). The latter data characterized contamination profiles within surficial sediment. Finally, the investigation provided some general observations regarding the location and composition of the contaminated sediment in Scuffletown Creek.

3.2 SAMPLING LOCATIONS AND PARAMETERS

A total of 63 sediment samples were collected from three locations in each of the four hot spot areas in Scuffletown Creek, for a total of 12 sampling locations. At each station, sediment samples were collected from the surface sediment (0-2 feet), 2-3 feet, 3 to 4 feet, 4 to 5 feet, and 5 to 6 feet intervals. Sediment samples were analyzed for Semi-Volatile Organics Analysis (EPA Method 8270C), Priority Pollutant Metals (EPA Method 6010B), Total Organic Carbon (EPA Method 9060), Particle Size Analysis of Soils (ASTM Method D422), Total Kjeldahl Nitrogen (EPA Method 351), Nitrate/Nitrite (EPA Method 353), Ammonia (EPA Method 350), Biochemical Oxygen Demand (EPA Method 405), Phosphate (EPA Method 365), Chemical Oxygen Demand (EPA Method 410), and Total Plate Count. Table 2-1, presented previously, provided for detail on analytical parameters.

3.3 DATA VALIDATION RESULTS

The laboratory analytical data packages, along with the Electronic Data Deliverables (EDD), were submitted concurrently to Foster Wheeler and to Meridian Science and Technology, Inc. (Meridian) of Annapolis, Maryland. Meridian performed data validation services according to the criteria established by Foster Wheeler in the Phase II SI/FI Project Work Plan (FWENC, 2000). Specifically, data validation was performed in accordance with the following EPA guidance documents:

- Region III Modifications to the National Functional Guidelines for Organic Data Review (EPA, September 1994).
- Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analysis (EPA, April 1993).
- Innovative Approaches to Data Validation (EPA Region III, 1995).

The following sections summarize the results of the data validation activities.

3.4 ANALYTICAL RESULTS

The following sections describe the areal location of the sediment contamination, as well as the relationship between the Foster Wheeler Phase II and EA Phase I data. In addition, some general observations are offered regarding the analytical data collected as part of this investigation.

3.4.1 Location of Sediment Contamination

Greatest contamination levels were encountered in the samples collected from borings SCF-03, SCF-07, and SCF-12. Figure 3-1 illustrates the locations of these sediment samples. For these samples, the greatest level of contamination occurs at the three to four foot interval below grade level. The samples collected from borings SCF-01, SCF-04, SCF-06, SCF-08, and SCF-09 had the greatest contamination at the surface, although the level of contamination in these samples is less than in the samples previously mentioned. With the exception of these observations, no observable vertical distribution of metals was noticed. The metals that appeared to be of greatest concentration are cadmium, chromium, copper, lead, antimony, zinc, mercury, and arsenic.

Generally, levels of all targeted compounds appear to be generally decreasing with sediment depth in Scuffletown Creek. Therefore, it appears that there would likely not be significant concentrations of compounds of concern present at depths of 6 feet or more.

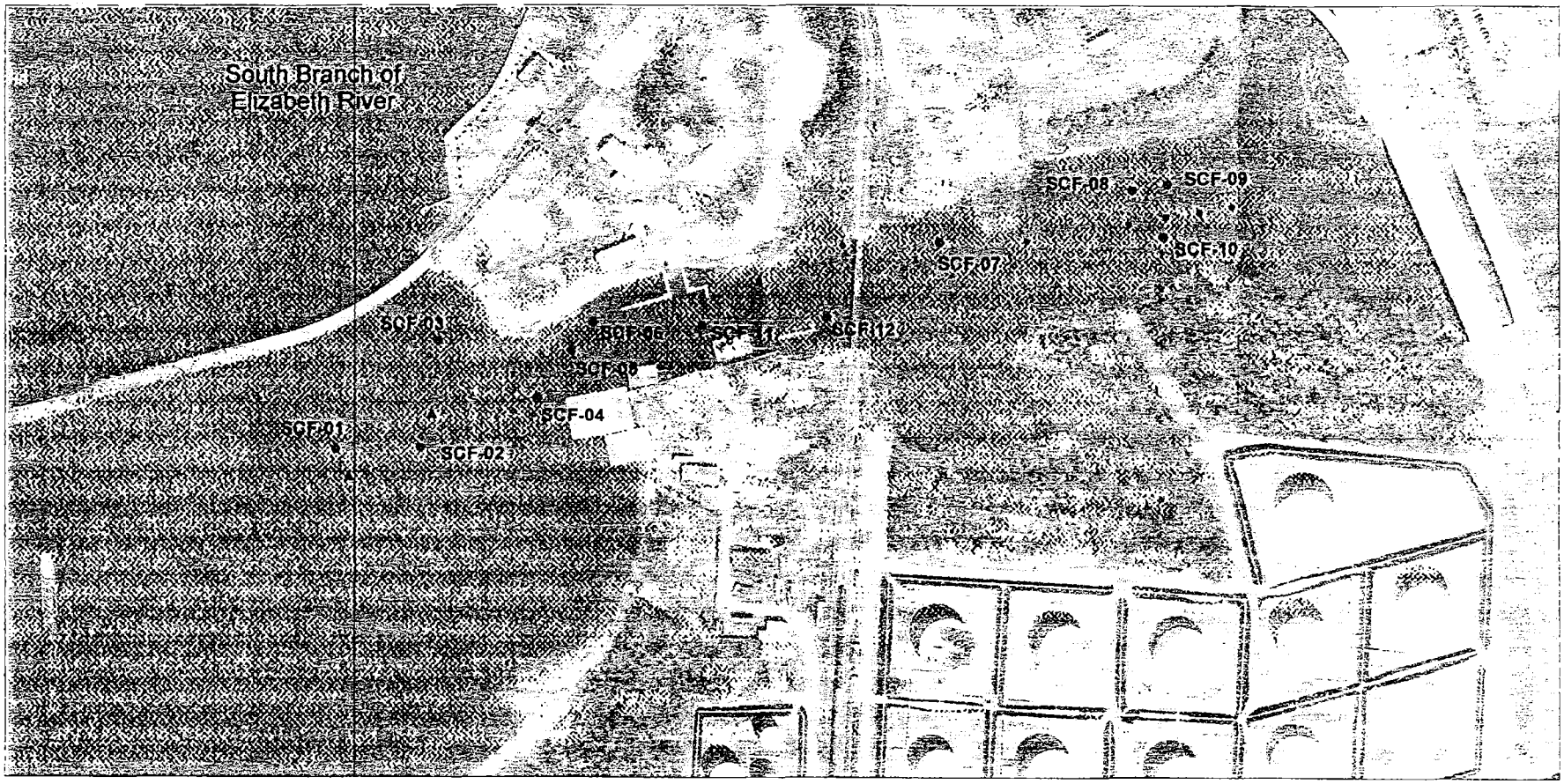
Generally, total organic carbon contamination is present in those locations comparable to the semi-volatile organic contamination. Tables 3-1 through 3-3 present the results of the metals, semi-volatile, and total organic carbon analytical results, respectively.

3.4.2 Comparison of Foster Wheeler and EA Data

Tables 3-4 and 3-5 present the Foster Wheeler Phase II data set, along with sample locations from EA's Phase I study that were closest in location to a Foster Wheeler sample. While there was some variation in the sample results, as could be expected due to the sediment transport characteristics associated with a tidal waterway, results obtained during both the Phase I and Phase II sampling episodes were relatively comparable with regard to the type and magnitude of sediment contamination.

3.5 SUMMARY AND CONCLUSIONS

Based on EA's Phase I results, Foster Wheeler obtained samples of Scuffletown Creek sediment from 12 borings conducted at depth during the week of July 31, 2000. A total of 63 sediment samples were collected and submitted to Severn Trent Laboratories for analysis of semi-volatile compounds, priority pollutant metals, and total organic carbon. The sample data were independently validated by Meridian Science and Technology.



Legend
- ● Sediment Sampling Locations
- • Pilings
- ▲ Buoy

100 0 100 200 Feet

U.S. Army Corp of Engineers
Norfolk District
Scuffletown Creek
Phase II Sediment Investigation
Chesapeake, VA

Figure 3-1
Surveyed Sediment Sampling Locations

FOSTER WHEELER ENVIRONMENTAL CORPORATION

A major problem regarding the MS/MSD controls for several borings was discovered during the validation of the metals data, resulting in appropriate qualification of those results. Low recoveries of copper, lead, and zinc analytes could bias these reported concentrations "low" for three of the borings. However, because the sediment appears to be relatively "inert" from the metals leachability standpoint, these qualified results should not adversely impact data usability nor the attainment of overall project goals. The remainder of the analytical data contained only minor problems that should not affect the validity of the laboratory data.

Primarily, sediment contamination by compounds of concern (i.e., polynuclear aromatic hydrocarbons) was located in the vicinity of borings SCF-03, SCF-07 and SCF-12. This contamination was present at maximum concentrations in the three-to-four-feet below grade interval. The remainder of the sediment contamination was present in greater amounts in the surface sediments (0-2 feet). Overall, the data collected by Foster Wheeler and EA generally arrive at comparable conclusions regarding both locations, types, and levels of sediment contamination for compounds of concern.

Table 3-1

Concentrations of Metals in Sediment Samples

Scuffletown Creek, Chesapeake, Virginia

Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Silver	Zinc	Mercury	Thallium
SCF01-0-2'	0.98	18.4	0.56	0.47	31.5	118	197	14.9	0.83	<0.39	281	1.7	<0.37
SCF01-2-3'	1.2	20.2	0.69	<0.050	28.4	77.9	167	16.5	0.7	<0.38	179	1.6	<0.36
SCF01-3-4'	<0.57	8.3	0.75	<0.050	26.9	20.1	30.2	22.2	<0.35	<0.43	83.7	0.32	<0.40
SCF01-4-5'	0.82	11.5	0.81	<0.040	25.6	15.4	26.6	18.5	3.8	<0.33	69.6	0.21	<0.31
SCF01-5-6'	<0.42	9.2	0.72	<0.040	23.2	15.8	29.9	17.0	<0.26	<0.32	72.1	0.1	<0.30
SCF02-0-2'	<0.41	13.6	0.72	<0.040	27.0	8.9	11.7	17.7	<0.25	<0.31	62.9	<0.10	<0.29
SCF02-2-3'	0.46	9.2	0.79	<0.040	28.7	9.1	12.4	18.9	<0.28	<0.34	63.8	<0.11	<0.32
SCF02-3-4'	<0.43	12.0	0.78	<0.040	29.0	9.5	12.7	19.5	0.47	<0.33	68.2	<0.10	<0.31
SCF02-4-5'	<0.41	8.6	0.89	<0.040	30.8	10.2	12.7	20.5	<0.25	<0.31	70	<0.090	<0.29
SCF02-5-6'	<0.38	8.1	0.84	<0.040	28.4	10	11.8	19.3	<0.24	<0.29	64.2	<0.090	<0.27
SCF03-0-2'	1.9	15.5	0.77	2.0	61.5	200	255	20.7	1.1	0.46	586	2.7	<0.38
SCF03-2-3'	1.6	15.6	0.79	2.0	62.2	184	277	18.9	0.96	0.49	502	2.6	<0.37
SCF03-3-4'	1.4	18.0	0.72	2.1	45.9	208	322	18.9	<0.35	1.2	472	3.1	<0.40
SCF03-4-5'	2.3	30.8	0.72	0.89	33.2	172	503	17.5	1.7	<0.37	338	4.2	<0.35
SCF03-5-6'	0.81	23.9	0.6	0.49	24.9	148	249	14.8	1.3	<0.34	269	3.1	<0.32
SCF04-0-2'	<0.55	12.0	0.47	0.74	34.0	142	136	14.3	0.79	<0.42	343	1.0	<0.39
SCF04-2-3'	<0.43	7.6	0.56	<0.040	27.4	26.6	39.1	15.8	0.35	<0.33	112	0.48	<0.31
SCF04-3-4'	<0.41	7.3	0.62	<0.040	26.7	11.6	17.3	17.2	<0.25	<0.31	74.7	<0.10	<0.29
SCF04-4-5'	<0.42	6.1	0.7	<0.040	29.1	6.0	12.7	17.6	<0.26	<0.32	65.6	<0.10	<0.30
SCF04-5-6'	<0.42	6.6	0.66	<0.040	27.3	7.3	12.9	15.8	<0.26	<0.32	67.6	<0.10	<0.30
SCF05-0-2'	<0.42	6.4	0.64	<0.040	28.7	5.7	12.5	16.9	<0.26	<0.32	65.4	<0.10	<0.30
SCF05-2-3'	<0.43	7.2	0.59	<0.040	25.9	7.0	14.9	15.4	<0.26	<0.32	63.3	<0.10	<0.31
SCF05-3-4'	<0.46	8.3	0.63	<0.040	27.4	6.7	13.6	17.7	<0.28	<0.35	68.2	<0.11	<0.33
SCF05-4-5'	<0.44	4.9	0.66	<0.040	28.2	6.3	12.8	17.6	<0.27	<0.33	66.4	<0.10	37.8
SCF05-5-6'	<0.46	6.2	0.66	<0.040	28.7	6.2	12.6	17.5	0.46	<0.35	67.3	<0.11	40.2
SCF06-0-2'	<0.35	6.3	0.2	<0.030	13.2	15.5	61.3	6.9	<0.22	<0.27	56.4	0.5	<0.25
SCF06-2-3'	<0.35	5.0	0.28	0.14	15.8	4.4	17.2	8.2	<0.22	<0.27	33.3	<0.080	31.9
SCF06-3-4'	<0.36	4.5	0.28	<0.030	16.0	2.2	7.2	9.0	<0.22	<0.28	33	<0.090	<0.26
SCF06-4-5'	<0.32	3.6	0.26	0.29	14.6	2.7	14.4	7.6	<0.20	<0.24	32.8	<0.070	<0.23
SCF06-5-6'	<0.34	3.8	0.24	<0.030	14.2	3.3	7.6	8.1	<0.21	<0.26	32	<0.080	<0.24
SCF07-0-2'	0.84	10.8	0.59	2.9	54.2	171	249	21.7	0.87	<0.45	693	1.8	<0.42
SCF07-2-3'	1.5	13.7	0.59	4.9	54.2	216	296	22.4	1.5	1.7	772	2.7	<0.52
SCF07-3-4'	1.9	15.4	0.43	2.5	29.8	142	299	14.7	1.1	<0.49	504	4.2	0.85
SCF07-4-5'	1.3	26.8	0.48	0.21	44.4	129	168	29.2	1.0	<0.40	279	1.2	<0.38
SCF07-5-6'	<0.45	7.3	0.6	<0.040	28.0	7.0	13.3	16.1	<0.28	<0.34	65.1	<0.1	<0.32

All results in mg/kg.

Table 3-1
Concentrations of Metals in Sediment Samples
Scuffletown Creek, Chesapeake, Virginia

Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Nickel	Selenium	Silver	Zinc	Mercury	Thallium
SCF08-0-2'	1.5	13.3	0.46	2.8	31.0	149	309	16.6	<0.40	0.52	592	4.0	0.87
SCF08-2-3'	0.87	11.9	0.61	0.91	25.6	90.7	186	14.6	0.73	<0.39	388	3.4	<0.36
SCF08-3-4'	0.55	10.8	0.47	0.75	25.3	94.3	172	12.5	0.48	<0.39	294	2.0	<0.37
SCF08-4-5'	<0.46	5.8	0.42	<0.040	22.3	5.0	11.3	12.2	<0.29	<0.35	53.1	<0.11	<0.33
SCF08-5-6'	<0.45	6.2	0.52	<0.040	26.1	6.5	11.7	15.7	<0.28	<0.34	59.3	<0.10	<0.32
SCF09-0-2'	<0.57	13.2	0.49	1.2	25.5	113	196	13.9	1.7	<0.44	370	2.6	0.55
SCF09-2-3'	<0.44	7.2	0.42	<0.040	22.3	31.1	68.9	10.8	0.27	<0.34	112	0.2	<0.32
SCF09-3-4'	<0.47	5.2	0.45	<0.040	24.2	4.1	9.9	12.1	0.3	<0.36	49.3	<0.11	<0.34
SCF09-4-5'	<0.45	5.6	0.48	<0.040	24.4	5.3	10.5	13.8	0.33	<0.35	56.3	<0.10	<0.32
SCF09-5-6'	<0.46	5.9	0.55	<0.040	27.8	5.7	11.5	15.8	<0.29	<0.35	62.2	<0.11	<0.33
SCF10-0-2'	<0.48	10.7	0.51	0.17	27.3	58.8	138	13.5	1.2	<0.37	218	1.6	<0.35
SCF10-2-3'	<0.50	7.1	0.55	<0.050	4.7	9.0	12.3	14.6	0.89	<0.38	56.6	<0.11	<0.36
SCF10-3-4'	<0.49	6.0	0.51	<0.050	27.3	8.7	11.9	14.9	0.74	<0.37	59.6	<0.11	<0.34
SCF10-4-5'	<0.49	5.3	0.51	<0.050	27.8	8.1	10.5	13	1.1	<0.37	55.5	<0.12	<0.35
SCF10-5-6'	<0.44	6.4	0.65	<0.040	23.7	8.6	11.7	16.5	0.97	<0.33	63.6	<0.10	<0.32
SCF11-0-2'	<0.49	9.4	0.51	<0.050	33.4	19.6	31.2	14.5	1.2	<0.37	89.8	<0.12	<0.35
SCF11-2-3'	<0.42	11.7	0.69	<0.040	23.7	10.2	14.0	17.5	0.68	<0.32	68.1	<0.10	<0.30
SCF11-3-4'	<0.42	13.3	0.66	<0.040	30.9	9.0	12.5	18.8	0.64	<0.32	73.4	<0.10	<0.30
SCF11-4-5'	<0.43	8.5	0.78	<0.040	32.4	10.1	14.2	19.7	1.1	<0.33	79	<0.10	<0.31
SCF11-5-6'	<0.41	6.2	0.72	<0.040	33.2	9.5	12..4	18.6	1.1	<0.31	146	<0.10	<0.29
SCF12-0-2'	0.57	14.9	0.51	1.2	40.0	141	249	16.0	0.77	<0.41	415	2.3	<0.38
SCF12-2-3'	0.75	14.0	0.51	2.1	37.8	181	237	20.8	1.5	1.1	516	3.0	<0.38
SCF12-3-4'	0.8	14.3	0.44	0.26	40.7	107	228	11.7	2.0	<0.35	228	1.8	<0.33
SCF12-4-5'	0.75	21.2	0.57	<0.050	24.3	116	198	15.5	1.6	<0.37	264	2.0	<0.34
SCF12-5-6'	<0.44	7.9	0.59	<0.040	28.1	9.2	12.8	19.2	0.47	<0.34	60.8	<0.11	<0.32
SCF04-4-5'D	<0.40	7.0	0.62	<0.040	26.7	6.8	13.0	16.0	<0.25	<0.30	65.3	<0.090	<0.28
SCF05-2-3'D	<0.43	7.2	0.68	<0.040	27.4	6.2	12.8	17.0	<0.27	<0.33	68.8	<0.1	<0.31
SCF06-5-6'D	<0.35	8.8	0.18	0.12	13.1	27.3	133	5.9	0.64	<0.27	97.4	0.47	<0.25

All results in mg/kg.

Table 3-2
Concentrations of Semivolatile Organic Compounds in Sediment Samples
Scuffletown Creek, Chesapeake, Virginia

Sample ID	2-Methyl-naphthalene	4-Methyl-phenol	Acenaph-thene	Acenaph-thylene	Anth-racene	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo(ghi) perylene	Benzo(k) fluoranthene	Benzo(a) anthracene
SCF01-0-2'	BDL	BDL	BDL	230J	440J	2,100	2,300	1,300	2,000	1,400
SCF01-2-3'	BDL	BDL	BDL	92J	130J	610J	730J	340J	610J	320J
SCF01-3-4'	BDL	BDL	BDL	BDL	BDL	97J	93J	BDL	100J	BDL
SCF01-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF01-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF03-0-2'	BDL	BDL	BDL	140J	340J	940	1,400	530J	1,200	690J
SCF03-2-3'	BDL	BDL	BDL	190J	440J	1,400	1,800	770J	1,800	700J
SCF03-3-4'	BDL	BDL	1,300	280J	880	2,700	4,100	1,300	3,000	2,300
SCF03-4-5'	BDL	BDL	220J	230J	380J	1,300	1,700	530J	1,400	740J
SCF03-5-6'	BDL	BDL	76J	180J	310J	12	1,600	620J	1,300	880
SCF04-0-2'	BDL	BDL	BDL	160J	300J	1,100	2,200	480J	780J	550J
SCF04-2-3'	BDL	BDL	BDL	BDL	110J	390J	890	150J	350J	180J
SCF04-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-0-2'	90J	BDL	130J	BDL	160J	610	970	220J	380J	440J
SCF06-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF07-0-2'	190J	110J	110J	230J	620J	1,900	4,700	1,500	1,400	1,700
SCF07-2-3'	240J	280J	480J	380J	1100J	3,400	7,600	2,900	2,500	3,200
SCF07-3-4'	1,000	750J	6,800	410J	6,200	7,600	15,000	4,900	5,100	12,000
SCF07-4-5'	BDL	BDL	BDL	BDL	140J	330J	590J	280J	170J	390J
SCF07-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF08-0-2'	180J	790J	160J	320J	770J	2,700	6,300	2,200	1,600	2,900
SCF08-2-3'	280J	680J	300J	150J	470J	1,100	1,800	870	550J	1,200
SCF08-3-4'	94J	390J	110J	100J	240J	560J	960	330J	290J	560J
SCF08-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF08-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-0-2'	BDL	120J	BDL	BDL	91J	440J	850J	320J	220J	380J
SCF09-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-0-2'	BDL	110J	BDL	BDL	88J	240J	370J	130J	160J	210J
SCF10-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	82J	BDL	BDL	BDL
SCF11-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF12-0-2'	110J	230J	140J	300J	840	2,300	4,300	1,200	1,400	2,300
SCF12-2-3'	89J	300J	180J	250J	500J	1,800	3,500	970	1,200	1,500
SCF12-3-4'	180J	77J	350J	360J	990	2,900	4,800	1,500	1,900	2,800
SCF12-4-5'	280J	BDL	180J	230J	550J	1,100	2,000	630J	630J	1,200
SCF12-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'D	BDL	BDL	BDL	BDL	BDL	100J	BDL	BDL	BDL	BDL
SCF05-2-3'D	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-5-6'D	BDL	BDL	BDL	BDL	120J	450J	1,300	290J	480J	390J

All results in ug/kg

Table 3-2
Concentrations of Semivolatile Organic Compounds in Sediment Samples
Scuffletown Creek, Chesapeake, Virginia

Sample ID	bis(2-Ethylhexyl) phthalate	Carbazole	Chrysene	Dibenzo-furan	Dibenzo(a,h) anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd) pyrene	Naph-thalene	Phen-anthrene	Pyrene
SCF01-0-2'	97J	140J	2,100	BDL	450	2,200	BDL	1,200	200J	870	3,300
SCF01-2-3'	BDL	BDL	620J	BDL	150J	1,100	BDL	340J	98J	140J	900
SCF01-3-4'	BDL	BDL	110J	BDL	BDL	96J	BDL	BDL	BDL	BDL	160J
SCF01-4-5'	BDL	BDL	BDL	BDL	BDL	88J	BDL	BDL	BDL	BDL	91J
SCF01-5-6'	BDL	BDL	BDL	BDL	BDL	100J	BDL	BDL	BDL	BDL	100J
SCF02-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF03-0-2'	110J	BDL	1,200	BDL	310J	2,500	BDL	500J	93J	190J	1,600
SCF03-2-3'	85J	BDL	1,700	BDL	280J	2,400	BDL	700J	110J	270J	1,900
SCF03-3-4'	BDL	BDL	3,800	120J	490J	5,800	210J	1,300	140J	690J	4,600
SCF03-4-5'	BDL	BDL	1,500	BDL	260J	2,400	140J	600J	95J	370J	1,900
SCF03-5-6'	BDL	BDL	1,600	BDL	300J	1,600	BDL	620J	96J	270J	1,500
SCF04-0-2'	230J	BDL	1,100	BDL	200J	920	BDL	580J	140J	400J	1,400
SCF04-2-3'	71J	BDL	330J	BDL	BDL	280J	BDL	170J	BDL	120J	710
SCF04-3-4'	180	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-0-2'	BDL	200J	630	170J	BDL	1,500	140J	270J	260J	1,800	1,600
SCF06-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF07-0-2'	280J	100J	1,900	180J	420J	3,800	140J	1,700	290J	530J	3,600
SCF07-2-3'	720J	150J	3,400	250J	770J	8,200	290J	3,200	480J	880J	7,300
SCF07-3-4'	BDL	BDL	15,000	2,800	1,500	28,000	6,200	5,600	820J	20,000	30,000
SCF07-4-5'	BDL	BDL	390J	BDL	BDL	900	BDL	270J	110J	250J	880
SCF07-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF08-0-2'	BDL	120J	2,600	210J	520J	6,600	180J	2,200	340J	650J	6,100
SCF08-2-3'	BDL	100J	1,400	230J	BDL	2,900	350J	830	490J	1,400	2,900
SCF08-3-4'	BDL	BDL	750J	92J	100J	1,500	130J	340J	180J	560J	1,300
SCF08-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF08-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-0-2'	BDL	BDL	370J	BDL	BDL	810J	BDL	350J	BDL	160J	720J
SCF09-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-0-2'	BDL	BDL	250J	BDL	BDL	640J	BDL	140J	94J	190J	410J
SCF10-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-3-4'	BDL	BDL	BDL	BDL	BDL	76J	BDL	BDL	BDL	BDL	78J
SCF11-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF12-0-2'	140J	150J	3,200	170J	500J	5,500	230J	1,400	320J	860	5,000
SCF12-2-3'	260J	BDL	1,700	98J	360J	2,600	120J	1,000	210J	460J	3,000
SCF12-3-4'	110J	130J	3,600	220J	540J	5,200	310J	1,700	390J	1,400	4,500
SCF12-4-5'	BDL	110J	1,400	260J	230J	2,800	220J	620J	1,200	1,100	2,100
SCF12-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'D	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-2-3'D	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-5-6'D	BDL	BDL	510J	BDL	BDL	1,000	BDL	290J	BDL	220J	2,800

All results in ug/kg

Table 3-3
Concentrations of Total Organic Carbon in Sediment Samples
Scuffletown Creek, Chesapeake, Virginia

Sample ID	Total Organic Carbon (mg/kg)
SCF01-0-2'	52,400
SCF01-2-3'	55,800
SCF01-3-4'	12,500
SCF01-4-5'	37,000
SCF01-5-6'	37,400
SCF02-0-2'	40,000
SCF02-2-3'	37,900
SCF02-3-4'	39,900
SCF02-4-5'	38,500
SCF02-5-6'	33,400
SCF03-0-2'	108,000
SCF03-2-3'	92,000
SCF03-3-4'	111,000
SCF03-4-5'	79,900
SCF03-5-6'	68,800
SCF04-0-2'	82,000
SCF04-2-3'	44,600
SCF04-3-4'	35,500
SCF04-4-5'	44,300
SCF04-5-6'	56,000
SCF05-0-2'	36,400
SCF05-2-3'	42,800
SCF05-3-4'	43,500
SCF05-4-5'	47,700
SCF05-5-6'	60,900
SCF06-0-2'	24,500
SCF06-2-3'	19,400
SCF06-3-4'	77,500
SCF06-4-5'	21,700
SCF06-5-6'	36,900
SCF07-0-2'	107,000
SCF07-2-3'	145,000
SCF07-3-4'	123,000
SCF07-4-5'	93,200
SCF07-5-6'	41,600
SCF08-0-2'	117,000
SCF08-2-3'	123,000
SCF08-3-4'	84,700
SCF08-4-5'	49,400
SCF08-5-6'	45,500

Table 3-3
Concentrations of Total Organic Carbon in Sediment Samples
Scuffletown Creek, Chesapeake, Virginia

Sample ID	Total Organic Carbon (mg/kg)
SCF09-0-2'	77,400
SCF09-2-3'	40,500
SCF09-3-4'	41,600
SCF09-4-5'	47,700
SCF09-5-6'	44,500
SCF04-4-5'D	35,900
SCF05-2-3'D	63,800
SCF06-5-6'D	28,800
SCF10-0-2'	88,900
SCF10-2-3'	68,700
SCF10-3-4'	56,200
SCF10-4-5'	65,800
SCF10-5-6'	34,800
SCF11-0-2'	84,700
SCF11-2-3'	48,100
SCF11-3-4'	43,500
SCF11-4-5'	36,000
SCF11-5-6'	39,000
SCF12-0-2'	66,400
SCF12-2-3'	113,000
SCF12-3-4'	65,700
SCF12-4-5'	78,700
SCF12-5-6'	43,300

Table 3-5
Comparison of Foster Wheeler and EA Semivolatile Analytical Data
Scuffletown Creek, Chesapeake, Virginia

Sample ID	2-Methyl-naphthalene	4-Methyl-phenol	Acenaph-thene	Acenaph-thylene	Anth-racene	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo(ghi) perylene	Benzo(k) fluoranthene	Benzo(a) anthracene
SCF01-0-2'	BDL	BDL	BDL	230J	440J	2,100	2,300	1,300	2,000	1,400
SCF01-2-3'	BDL	BDL	BDL	92J	130J	610J	730J	340J	610J	320J
SCF01-3-4'	BDL	BDL	BDL	BDL	BDL	97J	93J	BDL	100J	BDL
SCF01-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF01-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC024(0-1')*	BDL	BDL	BDL	BDL	BDL	300	400	160	240	170
SFC024(1-1.5')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC027(0-1')*	110	BDL	150	200	430	2,000J	2,900J	760J	1,800J	760
SFC027(1-2')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF03-0-2'	BDL	BDL	BDL	140J	340J	940	1,400	530J	1,200	690J
SCF03-2-3'	BDL	BDL	BDL	190J	440J	1,400	1,800	770J	1,800	700J
SCF03-3-4'	BDL	BDL	1,300	280J	880	2,700	4,100	1,300	3,000	2,300
SCF03-4-5'	BDL	BDL	220J	230J	380J	1,300	1,700	530J	1,400	740J
SCF03-5-6'	BDL	BDL	76J	180J	310J	12	1,600	620J	1,300	880
SFC004(0-1')*	BDL	BDL	BDL	110	270J	1,000	1,100	690	840	580J
SFC004(1-2')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-0-2'	BDL	BDL	BDL	160J	300J	1,100	2,200	480J	780J	550J
SCF04-2-3'	BDL	BDL	BDL	BDL	110J	390J	890	150J	350J	180J
SCF04-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF031(0-1')*	BDL	BDL	BDL	BDL	BDL	190	370	BDL	120	96

All results are in ug/kg. Asterisk denotes sample collected by EA.

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Table 3-5

Comparison of Foster Wheeler and EA Semivolatile Analytical Data
Scuffletown Creek, Chesapeake, Virginia

Sample ID	2-Methyl-naphthalene	4-Methyl-phenol	Acenaph-thene	Acenaph-thylene	Anth-racene	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo(ghi) perylene	Benzo(k) fluoranthene	Benzo(a) anthracene
SCF05-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF05-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF032(0-1')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF032(1-2')*	BDL	BDL	1,000	410	2,600	3,300	6,900	1,900	2,500	3,900
SCF06-0-2'	90J	BDL	130J	BDL	160J	610	970	220J	380J	440J
SCF06-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF06-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF035(0-1')*	BDL	BDL	BDL	BDL	BDL	800	1,400	BDL	BDL	BDL
SFF035(1-2')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF07-0-2'	190J	110J	110J	230J	620J	1,900	4,700	1,500	1,400	1,700
SCF07-2-3'	240J	280J	480J	380J	1100J	3,400	7,600	2,900	2,500	3,200
SCF07-3-4'	1,000	750J	6,800	410J	6,200	7,600	15,000	4,900	5,100	12,000
SCF07-4-5'	BDL	BDL	BDL	BDL	140J	330J	590J	280J	170J	390J
SCF07-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC079(0-1')*	430	490	450	440	1,200	3,600J	5,900J	2,600J	4,000J	3,600J
SFC079(1-2')*	170	200	280J	270J	740J	1,300J	1,700J	1,100J	1,300J	1,500J
SCF08-0-2'	180J	790J	160J	320J	770J	2,700	6,300	2,200	1,600	2,900
SCF08-2-3'	280J	680J	300J	150J	470J	1,100	1,800	870	550J	1,200
SCF08-3-4'	94J	390J	110J	100J	240J	560J	960	330J	290J	560J
SCF08-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF08-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC069(0-1')*	85	96	BDL	80	150	540J	870J	410J	590J	400
SFC069(1-2')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

All results are in ug/kg. Asterisk denotes sample collected by EA.

Table 3-5

Comparison of Foster Wheeler and EA Semivolatile Analytical Data

Scuffletown Creek, Chesapeake, Virginia

Sample ID	bis(2-Ethylhexyl) phthalate	Carbazole	Chrysene	Dibenzo-furan	Dibenzo(a,h) anthracene	Fluor-anthene	Fluorene	Indeno(1,2,3-cd) pyrene	Naph-thalene	Phen-anthrene	Pyrene
SCF01-0-2'	97J	140J	2,100	BDL	450	2,200	BDL	1,200	200J	870	3,300
SCF01-2-3'	BDL	BDL	620J	BDL	150J	1,100	BDL	340J	98J	140J	900
SCF01-3-4'	BDL	BDL	110J	BDL	BDL	96J	BDL	BDL	BDL	BDL	160J
SCF01-4-5'	BDL	BDL	BDL	BDL	BDL	88J	BDL	BDL	BDL	BDL	91J
SCF01-5-6'	BDL	BDL	BDL	BDL	BDL	100J	BDL	BDL	BDL	BDL	100J
SFC024(0-1')*	BDL	BDL	320	BDL	BDL	150	BDL	140		80	430
SFC024(1-1.5')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF02-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC027(0-1')*	BDL	BDL	1,300	150	BDL	1,200	140	790J	430	570	2,200
SFC027(1-2')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF03-0-2'	110J	BDL	1,200	BDL	310J	2,500	BDL	500J	93J	190J	1,600
SCF03-2-3'	85J	BDL	1,700	BDL	280J	2,400	BDL	700J	110J	270J	1,900
SCF03-3-4'	BDL	BDL	3,800	120J	490J	5,800	210J	1,300	140J	690J	4,600
SCF03-4-5'	BDL	BDL	1,500	BDL	260J	2,400	140J	600J	95J	370J	1,900
SCF03-5-6'	BDL	BDL	1,600	BDL	300J	1,600	BDL	620J	96J	270J	1,500
SFC004(0-1')*	480J	54J	990J	BDL	370	1,000J	BDL	620	180	290J	1,000J
SFC004(1-2')*	180	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-0-2'	230J	BDL	1,100	BDL	200J	920	BDL	580J	140J	400J	1,400
SCF04-2-3'	71J	BDL	330J	BDL	BDL	280J	BDL	170J	BDL	120J	710
SCF04-3-4'	180	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF04-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF031(0-1')*	BDL	BDL	190	BDL	BDL	170	BDL	95	BDL	BDL	250

All results are in ug/kg. Asterisk denotes sample collected by EA.

Table 3-5
Comparison of Foster Wheeler and EA Semivolatile Analytical Data
Scuffletown Creek, Chesapeake, Virginia

Sample ID	bis(2-Ethylhexyl) phthalate	Carbazole	Chrysene	Dibenzo-furan	Dibenzo(a,h) anthracene	Fluor-anthene	Fluorene	Indeno(1,2,3-cd) pyrene	Naph-thalene	Phen-anthrene	Pyrene
SCF09-0-2'	BDL	BDL	370J	BDL	BDL	810J	BDL	350J	BDL	160J	720J
SCF09-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF09-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC054(0-1')*	240	BDL	670	98	170J	1,200	100	470J	250	430	1,800
FC054(1-1.75')	BDL	BDL	170	BDL	BDL	350	BDL	86J	73	110	400
SCF10-0-2'	BDL	BDL	250J	BDL	BDL	640J	BDL	140J	94J	190J	410J
SCF10-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-3-4'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF10-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFC086(1-2')*	BDL	BDL	470	BDL	140	960	BDL	270	91	350	950
SCF11-0-2'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-2-3'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-3-4'	BDL	BDL	BDL	BDL	BDL	76J	BDL	BDL	BDL	BDL	78J
SCF11-4-5'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF11-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF036(0-1')*	BDL	BDL	170	BDL	BDL	220	BDL	110	BDL	90	270
SFF036(1-1.8')*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SCF12-0-2'	140J	150J	3,200	170J	500J	5,500	230J	1,400	320J	860	5,000
SCF12-2-3'	260J	BDL	1,700	98J	360J	2,600	120J	1,000	210J	460J	3,000
SCF12-3-4'	110J	130J	3,600	220J	540J	5,200	310J	1,700	390J	1,400	4,500
SCF12-4-5'	BDL	110J	1,400	260J	230J	2,800	220J	620J	1,200	1,100	2,100
SCF12-5-6'	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SFF042(0-1')*	3,100	1,100	2,500	200	580J	3,900	300	1,000J	400	1,100	4,000
SFF042(1-1.8')*	3,300	BDL	4,400	240	690	6,900	560	1,500	340	2,800	6,200

All results are in ug/kg. Asterisk denotes sample collected by EA.

4.0 REMEDIAL ALTERNATIVE DEVELOPMENT AND SCREENING

4.1 BACKGROUND

The Phase I Sediment Investigation, completed in 1999, identified several potential contaminants of concern, including semivolatile organic compounds (SVOCs) and inorganic analytes, in the surficial sediments collected from the Scuffletown Creek site. Based on the results of sediment sampling and analysis, the Norfolk USACE delineated four "hot spot" areas of concern within Scuffletown Creek. These hot spots are characterized by elevated levels of potential contaminants of concern.

Foster Wheeler conducted a Phase II Sediment Investigation and Feasibility Investigation at Scuffletown Creek. The purpose of these studies is to determine the vertical extent of sediment contamination and to develop preliminary options for the remediation of the impacted sediments at the site. Remedial alternative screening and development was conducted in three consecutive steps: i) literature search and preliminary screening; ii) bench-scale treatability studies; and iii) detailed analysis. After completing the literature search and preliminary screening, Foster Wheeler prepared a Technical Memorandum for submittal to the Norfolk District USACE. Remedial alternative screening and development were conducted consistent with the goals of the Scuffletown Creek Program: to remediate "hot spot" areas of concern, thereby assisting in restoration of habitats associated with this highly stressed estuarine community.

The literature search focused on remedial technologies applicable to the contaminants of concern identified in Scuffletown Creek sediments. The remedial alternatives were researched using Foster Wheeler archives and pertinent external resources. The websites and software used for this research include:

- Environmental Protection Agency (www.epa.gov)
- The Electric Power Research Institute (www.epri.com)
- Envirosource (www.envirosource.com)
- Remediation Technologies Development Forum (www.rtdf.org)
- The Groundwater Remediation Technologies Analysis Center (www.gwrta.com)
- The Vendor Information System for Innovative Treatment Technologies (VISITT software, available from EPA website)

The reports utilized for this research were provided by the University of California and the Environmental Protection Agency. The reports and reference numbers are listed below:

- Innovative Treatment Technologies: Overview and Guide Information Sources (EPA/540/9-91/002)

- Completed North American Innovative Remediation Technology Demonstration Projects (EPA/B96/002)
- Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA/540/R95/512)
- How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers (EPA/510/B95/007)
- Remediation of Contaminated Sediments (EPA/625/691/028)
- Selecting Remediation Techniques for Contaminated Sediment (EPA/823/B93/001)
- ARCS Remediation Guidance Document (EPA/905/B94/003)
- Applications of Bioremediation in the Cleanup of Heavy Metals and Metalloids (Frankenberger, Jr. and Losi, University of California)

The preliminary screening of remedial technologies serves to eliminate those technologies that do not warrant further consideration. Elimination from consideration was based on factors such as limiting site-specific physical or chemical conditions, lack of well-demonstrated technology applications, high relative cost, constructability or implementability concerns, anticipated difficulty of operation or maintenance, or inconsistency with Elizabeth River Environmental Restoration Program goals. In the following pages, the potential remedial technologies considered are briefly described and evaluated. Those options that were retained from preliminary screening are summarized in Section 4.3, and subsequently underwent treatability testing and detailed evaluation in the Feasibility Study.

4.2 TREATMENT TECHNOLOGY EVALUATION

BIOLOGICAL TECHNOLOGIES

Bioremediation denotes a variety of processes that involve the use of native microbes or selectively adapted bacteria to degrade a variety of organic compounds. Biodegradation processes can be aerobic or anaerobic, depending on the target contaminants. While biodegradation has been demonstrated to be effective mainly on organics, limited studies have been performed on its applicability for inorganic contamination. However, studies are being conducted on the possible usefulness of microbial metabolic activity for immobilization, or reduction to preferable forms, of certain metals. Hence the following biotechnologies that are discussed may have positive results on both organic and inorganic contamination in sediments.

Under ideal conditions, *in situ* treatment would accelerate the degradation of contaminants. However, it is very difficult to control the process and environmental conditions during treatment conducted in the complex sediment-water ecosystem. While much research is being performed, limited effectiveness has been demonstrated for *in situ* biodegradation. The effectiveness of *ex situ* biodegradation has been demonstrated more extensively.

Bioventing

Description:

Bioventing is an *in situ* remediation technique that uses indigenous microorganisms to biodegrade organic compounds adsorbed to soils. Injection wells are installed to deliver air to the soil, where microorganisms utilize the oxygen, along with nutrients that may be added, to degrade organics. This technology enhances the natural microbial degradation process of organics.

Initial Screening:

The ability of a soil/sediment to transmit air, which is of prime importance to bioventing, is reduced by the presence of water, which can block the soil pores and reduce airflow to bacteria. Hence, this technology is not suitable for saturated sediments. Additionally, this process is effective mainly on aerobically biodegradable constituents. The presence of high concentrations of heavy metals can be toxic or inhibit the growth and reproduction of bacteria responsible for biodegradation. Finally, this technology would be physically impractical to construct and maintain within a tidal waterway that is up to ten feet deep and used by the public for navigation. *Since this technology is not appropriate for conditions at the site, it is not retained for further evaluation.*

Landfarming / Solid Phase Composting

Description:

Landfarming is an *ex situ* remediation technology that reduces concentrations of contaminants through closely-controlled microbial activity, resulting in contaminant degradation. Solid material (e.g., soil, sediment) is placed in layers from 6 inches to several feet high across a prepared surface within a vessel or within a lined outdoor trench. Microbial activity is stimulated within the soil through aeration, tilling and/or the addition of nutrients and moisture. Leachate and contaminated liquids that are generated are collected by underdrains for treatment and/or disposal.

Initial Screening:

Landfarming has been demonstrated to be effective mainly for treating organic constituents with slow biodegradation rates. The structures necessary for this system would require a large amount of space but relatively little capital investment; also, this space could be shared with equipment required for a supplementary process selected for metals removal. Additionally, saturated sediments may require dewatering as a pretreatment. *This technology is retained for further consideration because it is proven and effective in treating organics.*

Phytoremediation

Description:

This *in situ* technique involves the cultivation of plant species that translocate metals from sediments to plant roots, stems, and leaves; and degrade organic compounds such as polynuclear aromatic hydrocarbons (PAHs). Upon maturity, the plants are harvested and either incinerated or composted. A halophyllic species (chloride tolerant) would be necessary for an estuarine system such as Scuffletown Creek.

Initial Screening:

This technology has been shown effective in removing metals and PAHs and is relatively low in cost. However, it is most applicable for soils with low levels of contamination at shallow depths; in contrast, contamination in Scuffletown Creek sediment has been classified as *severe* and could be impacting sediment at depth within the creek basin. *This technology is eliminated from further evaluation due to the availability of other options, such as soil washing, that are better demonstrated and have a broader range of proven treatment approaches.*

Slurry Phase Biological

Description:

Slurry-phase biological treatment is an *ex situ* process in which contaminated sediment is treated in a "bioreactor" tank or within a specially-prepared portion of a landfarm cell. A sediment-water slurry is aerated and mechanically mixed with appropriate nutrients, so that the optimum environment for microorganisms to degrade organic compounds is maintained. The water and solids may then be separated and disposed separately.

Initial Screening:

Due to the increased contact between microorganisms and organic contaminants, slurry-phase biological treatment promotes rapid biodegradation compared to other biological treatment processes. The effectiveness of slurry-phase treatment in degrading PAH compounds, in particular, has been demonstrated. *Slurry-phase biological treatment is therefore retained for further evaluation.*

PHYSICAL/ CHEMICAL TECHNOLOGIES

Capping

Description:

Capping involves the application of a layer of material such as clean sediment, sand, gravel, and/or geotextile fabric to stabilize and isolate contaminated sediments. The cap may include

Initial Screening:

Drawbacks to this method include possible resuspension of contaminated sediments during dredging, volume increase due to the addition of reagents, and the risks of exposure during handling. Also, an additional treatment process may be required to treat the organic compounds. *However, this option is retained for further evaluation, as it is an effective and well-developed treatment technology, especially for metals.*

In Situ Stabilization

Description:

In situ stabilization is a process whereby sediments remain in-place while being converted to a stable cement-type matrix. A reagent such as cement/fly ash slurry would be injected into the sediments using a hollow drill with an injection point at the bottom of the shaft. Solid vertical columns are formed, and are overlapped by subsequent borings.

Initial Screening:

In situ stabilization is a recent development that has not been demonstrated in a large scale sediment application. It involves similar challenges regarding process control and efficiency posed by other *in situ* sediment treatments, particularly with consideration to implementability in this tidal waterway used for navigation. *This technology is eliminated from further evaluation due to the fact that its implementability as an in situ treatment has not been well demonstrated.*

Soil Flushing

Description:

In situ soil flushing is the in-place extraction of organics and/or metals by flushing an aqueous solution, containing additives such as acids or surfactants (detergents), through the sediments. Injection and extraction wells, as well as a chemical feed system would be installed for this injection/recirculation process.

Initial Screening:

A large volume of wastewater would be generated and would require management via treatment and discharge. Design of this process could be complex for treatment of multiple types of contaminants concurrently. Soil flushing is also not recommended for media with a high content of silt and clay, such as that in Scuffletown Creek. *Like other in situ treatments, implementation of this technology would pose many challenges regarding process control and efficiency, as well as access, and is therefore eliminated.*

Soil Vapor Extraction

Description:

As another *in situ* treatment type, soil vapor extraction (SVE) involves installation of wells throughout the impacted material. Through a network of piping, a vacuum is applied to the wells to draw off volatile and/or semivolatile organic compounds in vaporized form. For saturated sediments, soil vapor extraction is used in combination with air sparging, which uses additional wells to pump air into the sediment to vaporize the contaminants. The removed vapor usually requires further treatment via thermal oxidation or carbon adsorption prior to release to the atmosphere.

Initial Screening:

This process option is not technically feasible for implementation within a waterway. It would be necessary for the SVE wells to be placed within an unsaturated zone to draw out the contaminant vapors that bubble up from the saturated zone. *Since this is an entirely saturated setting, SVE treatment is not retained for further evaluation.*

Soil Washing

Description:

Soil washing of excavated sediment involves separating fine- and coarse-grained sediments, and then treating the relatively smaller volume of fine-grained sediments, to which the majority of contaminants adhere. The fine-grained sediments are treated with doses of polymers or surfactants, and mechanically agitated to liberate contaminants from the soil particles. The larger volume of coarse-grained sediments are tested and may simply be returned to the site as clean. This process only requires treatment of a contaminated fraction of the material, with a minimal volume remaining to be disposed. Soil washing can be used for semivolatile organics and metals.

Initial Screening:

Soil washing would generate a large volume of wastewater that would require management. This technology involves high fixed costs for mobilization and demobilization. Modular systems have been developed that are appropriate for waterway locations. *This technology's versatility and effectiveness for treating both organics and metals makes it a viable option that will be retained for further consideration.*

Solvent Extraction

Description:

Solvent extraction is the separation of contaminants from sediment by bringing it into contact with organic solvents. The sediment would be excavated and treated with extractant solution in a soil washing system. The spent extraction solution, containing concentrated amounts of contaminants, would be further treated before disposal. The sediment would be rinsed, neutralized if necessary, and could then be used as backfill.

Initial Screening:

Solvent extraction is generally used for removing semivolatiles; extraction of metals could be accomplished using an acid solution, but this is a more expensive process. A large volume of wastewater would be generated that would require management via treatment and discharge. *Solvent extraction is eliminated from further evaluation because it would be impractical and cost prohibitive to develop comprehensive process systems for treating both organics and organics.*

THERMAL TECHNOLOGIES

Thermal technologies are those that involve heating sediments above ambient temperatures to destroy or isolate contaminants. They are the most expensive technologies to implement, particularly due to operation and maintenance costs. Most are best suited to treatment of organic compounds, including PAHs, with the exception of vitrification, which also immobilizes inorganic compounds.

Incineration

Description:

Incineration, the most commonly used thermal treatment, can be used to destroy all forms of combustible waste materials, including organic contaminants. Conventional incineration systems such as multiple hearth, rotary kiln, infrared, and fluidized bed treat highly contaminated soils at high temperatures (1200°F to 1800°F in the primary chamber and 1400°F to 2400°F in the secondary chamber). The off-gas and wastewater streams produced must be treated due to contaminant transfer.

Initial Screening:

High temperature incineration is suitable for removal of organic compounds only; it does not destroy heavy metals and may actually increase their leachability. In addition, incineration of sediments would be very expensive, as all traces of moisture must first be removed. *This process would be inefficient and possibly cost prohibitive for use with saturated sediments; therefore, high temperature incineration is eliminated from consideration.*

with respect to the unique site conditions of this estuarine location. Table 4-1 summarizes the results of this Preliminary Screening of Alternatives for the Scuffletown Creek sediment remediation program.

As a result of Foster Wheeler's literature search and preliminary screening, four treatment technologies were recommended to move forward in the Feasibility Study: Landfarming/Solid Phase Composting, Slurry Phase Biological Treatment, *Ex-Situ* Stabilization, and Soil Washing. Each of these technologies warranted moving forward into Task 6-Treatability Studies and, subsequently, Task 7-Detailed Analysis of Alternatives.

Table 4-1
Summary of Remedial Alternative Development and Screening for Scuffletown Creek Contaminated Sediment

		Retained for Further Consideration		
Technology Type	***Process Option***	***Yes***	***No***	***Comments***
BIOLOGICAL TREATMENT	Bioventing		✓	Impractical for application to sediments in a waterway.
	Landfarming/Solid Phase Composting	✓		Applicable to contaminants of concern, conducive to use with other unit operations, and relatively cost-effective.
	Phytoremediation		✓	Best suited for application to shallow site soils, not well demonstrated.
	Slurry Phase Biological	✓		Well demonstrated for PAH compounds, could lend itself to rapid degradation within a wet sediment matrix.
PHYSICAL/ CHEMICAL TREATMENT	Capping		✓	Impractical for sediment contamination in a waterway, cost prohibitive, and does not meet overall program goals.
	Chemical Oxidation		✓	Not well demonstrated and impractical for contaminated sediment in a waterway.
	Ex-Situ Stabilization	✓		Effective and well demonstrated for contaminants of concern (e.g., metals).
	In-Situ Stabilization		✓	Not well demonstrated and impractical for contaminated sediment in a waterway.
	Soil Flushing		✓	Not suitable for Scuffletown Creek sediment (which is high in silt and clay content), and costly to design and control.
	Soil Vapor Extraction		✓	Not suitable for contaminant removal within saturated settings.
	Soil Washing	✓		Very effective for both PAH compounds and metals. Although potentially costly, modular systems are available for waterway application.
	Solvent Extraction		✓	Although effective for both PAH compounds and metals, process is very complex and expensive.
THERMAL TREATMENT	Incineration		✓	Not effective for metals; process system plus ancillary air pollution control and wastewater treatment could be cost prohibitive.
	Thermal Desorption		✓	Not suitable for metals, probably cost prohibitive for removing PAH compounds from saturated sediment.
	Vitrification		✓	Emerging technology not well suited for saturated sediment.

5.0 TREATABILITY STUDIES

Treatability studies were conducted on two bulk sediment samples collected from Scuffletown Creek, selected to represent the most highly contaminated sediments ("high strength") and sediment containing more typical concentrations of contaminants ("average strength"). The treatability study began with comprehensive characterization of the two sediment samples, followed by preparation of a Test Plan and subsequent bench-scale testing of designated process technologies. This section summarizes the results of these studies.

The Final Treatability Study Report, prepared by HydroQual under Foster Wheeler's direction, is included as Appendix C.

5.1 SEDIMENT CHARACTERIZATION

The characterization of the sediment samples indicated that the only organic compounds present at detectable concentrations in both the high and average strength sediment samples were PAHs. The total PAH concentrations in the high and average strength sediments were 48,100 µg/kg and 28,600 µg/kg, respectively. Semi-volatile TCLP results on the high strength sediment were all below detection limit levels.

The metals concentrations in the two sediment samples were similar. With the exception of antimony, beryllium, cobalt, silver and thallium, all TAL metals were present at detectable concentrations. However, with the exception of lead in the average strength sediment, all TCLP metals were below detection limit levels. The lead TCLP level in the average strength sediment sample was 0.166 mg/L, which is below the regulatory TCLP limit for lead of 5 mg/L. Based on these analyses and upon obtaining the Norfolk District USACE's concurrence, a treatability study on stabilization technology was eliminated from the planned testing protocol. The characterization data indicated that treatment of metals to meet off-site disposal requirements would not be necessary.

Both sediment samples had similar levels of the conventional parameters. The COD concentration in both sediments was approximately 120,000 mg/L. Both sediments contained 52 percent solids and 14 mg/kg ammonia. The total plate counts in the high and average strength sediment were 150,000 and 130,000 cfu/mL, respectively. Particle size distribution analysis indicated that the high strength sediment contained a higher fraction of fine particles.

Thus, laboratory-scale treatability studies were performed on only three of the four technologies that were retained during the preliminary screening evaluation: Solid Phase Composting, Slurry Phase Biological Treatment, and Soil Washing.

5.2 SUMMARY OF TEST RESULTS

5.2.1 Solid Phase Composting

Treatment by solid phase composting was tested by mixing sediment with an inoculum (consisting of a 2:1 ratio of wood chips to municipal compost) at two ratios (i.e., 2:1 and 5:1). Solid phase composting was tested under both aerobic and anaerobic conditions on both the high and average strength sediment for a period of 21 days. PAH removal by solid phase composting ranged from 24.3% to 74.4%. *(Note: One reactor showed an increase in PAH concentration after treatment and is not included in this range. This was probably a result of the variability of PAH concentrations in the sediments and the difficulty in obtaining a completely mixed sample without "pockets" of higher contamination.)* The highest removal of PAHs (i.e., 74.4%) was observed in the aerobic reactor treating the high strength sediment with an inoculum to sediment ratio of 2:1.

5.2.2 Slurry Phase Biological Treatment

Slurry phase biological treatment was tested by creating a 10 to 15 percent slurry of sediment in an acclimated biological sludge from a refinery wastewater treatment plant. Slurry phase treatment was tested under aerobic conditions on both high and average strength sediment for a period of 4 weeks. Five samples were collected over the operating period and showed varying levels of PAH removal. The final samples indicated 86% removal of PAHs from the high strength sediment and 99% removal of PAHs from the average strength sediment by slurry phase treatment. It should be noted that the slurry phase treatment operating and sampling procedure required the treated sediment to be separated from the slurry by a process similar to soil washing. As a result, some of the PAH removal may be attributed to the soil washing process; based on the soil washing results, it is possible that 20 to 80 percent of the removals could be attributed to soil washing.

5.2.3 Soil Washing

Treatment of sediment by soil washing was tested using a water wash, double volume water wash, high temperature water wash, acid wash, and surfactant (Igepal CA-270) wash at two doses (20 mg/g and 200 mg/g). Both the high and average strength sediment were subjected to each treatment. The highest removals of PAHs observed on the high strength sediment were achieved using a hot water wash (40°C), with a 98% PAH removal, and surfactant wash at 20 mg/g, with a 96% PAH removal. The highest removals of PAHs observed on the average strength sediment were achieved using a double volume water wash (85% PAH removal) and surfactant wash at 20 mg/g (83% PAH removal).

5.2.4 Summary of Test Results

The overall results of laboratory-scale treatability testing are summarized by technology type in Table 5-1.

TABLE 5-1
Results of Laboratory-Scale Treatability Testing

Technology Type	PAH Removal Range (%)	Comments
Solid Phase Composting	24-74%	• Highest removal attained using inoculum to sediment ration of 2:1 in aerobic reactor (high-strength sediment).
Slurry Phase Biological	86-99%	• Removal efficiency may be overstated because sampling procedure involved a process similar to soil washing; therefore, 20-80% of removals could be attributed to soil washing.
Soil Washing	83-96%	• Highest removals attained using hot water wash and surfactant wash (for high-strength sediment). • Highest removals attained using double volume water wash and surfactant wash (for average strength sediment).

5.3 CONCLUSIONS

Throughout the treatability studies, significant variations were observed in the removal of PAHs from the sediment. These variations were observed within each technology tested, between the technologies and between the average and high strength sediment samples. Of the three technologies tested, the highest PAH removals were associated with slurry phase biological treatment on the average strength sediment (99% PAH removal) and soil washing on the high strength sediment (96-98% PAH removal). Solid phase composting did not achieve PAH removal percentages as high as the other two processes; however, 74% removal of PAHs from the high strength sediment was achieved over a 21 day period through composting. Since composting is a slower process than either soil washing or slurry phase treatment, this removal percentage is significant. Despite the variations in PAH removal, a general conclusion that can be drawn from the treatability study is that all three of the technologies are capable of achieving some significant level of removal of PAHs from the Scuffletown Creek sediment.

Overall, the treatability study has shown that any of the three technologies tested could be used to effectively treat the dredged sediments from Scuffletown Creek. Identification of the optimum remedy requires an assessment of certain other factors, including total volume to be treated, expected contaminant levels, ability to segregate, final disposition and cleanup levels for disposition, which will be addressed in the Detailed Analysis of Alternatives (Task 7).

6.0 DETAILED ANALYSIS OF ALTERNATIVES

6.1 EVALUATION CRITERIA

Of the seven evaluation criteria developed in the work plan (see Table 2-2), the following three are considered to be the most fundamental or the "first tier" criteria: Cost, Implementability, and Effectiveness. The "first-tier" criteria emphasize the fundamental long-term value of the remedial approach, relative to other alternatives; as well as the potential for the remedial system to be successfully constructed and operated at the site. "First-tier" criteria are particularly useful during preliminary screening steps. The remaining four criteria, Overall Protection of Human Health and the Environment; Compliance with ARARs; Reduction of Toxicity, Mobility, or Volume; and Stakeholder Acceptance are considered critical for rounding out the Detailed Analysis of Alternatives.

6.2 PROCESS SCHEMATICS

In order for the evaluation of the remedial alternatives against the seven criteria to be an effective decision-making tool for project stakeholders, an understanding of the process technologies under consideration is essential. With that objective in mind, this section presents schematic diagrams and additional relevant information on treatment cycle duration time, volume of sediment treated per batch, and area requirements for the technology options. Depending on the proprietary processes and equipment available from vendors, there can be a great deal of variation in the implementation of the technologies. Hence, the process diagrams have been kept somewhat general to allow for the range of possibilities. The model design parameters are based on preliminary assumptions and represent possible scenarios to consider; however, the actual project specifications will vary from this starting point, and more precise parameters will be developed at the design stage.

6.2.1 Landfarming Process and Equipment Information (Alternative 2 and Alternative 5)

Landfarming is a treatment process whereby dewatered sediments are spread in a layer; and contaminant concentrations are reduced by microbial activity, which is stimulated by the addition of nutrients and bulking agents, and aeration. It is a relatively simple technology requiring low capital investment, but it may not be suitable if rapid treatment is required. A model landfarming schematic design is presented in Figure 6-1. Sediments would be treated in a biocell sized to handle batches of 2300 cubic yards, where they would be mixed, aerated, and subjected to nutrient addition. At eight to ten weeks of treatment per cycle, four to five years would be required to treat all of the sediments.

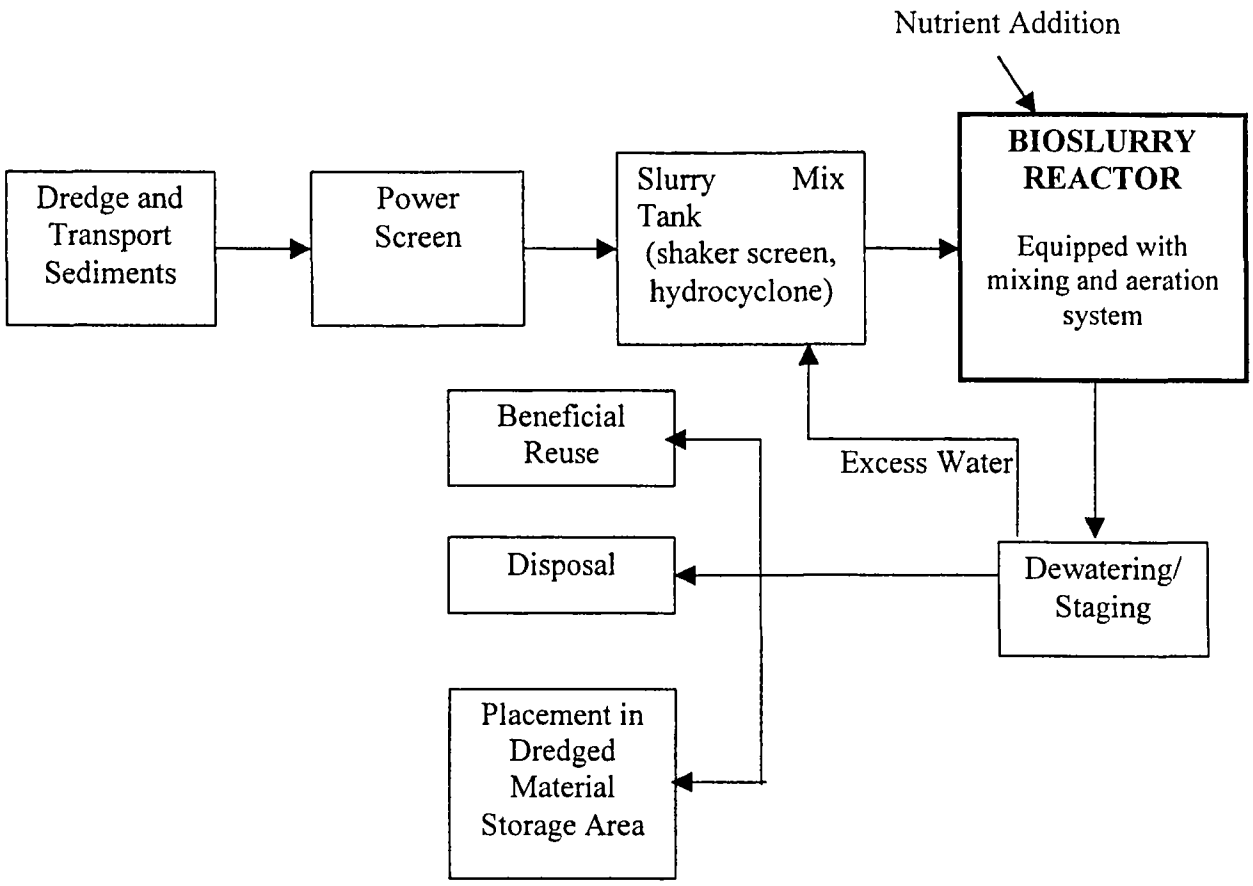
6.2.2 Slurry Phase Biological Treatment Process and Equipment Information (Alternative 3 and Alternative 5)

Slurry-phase biological treatment entails treating a sediment-water slurry in a bioreactor cell, where the slurry is aerated and mixed with nutrients. This stimulates microbial activity to degrade contaminants. Biodegradation in the slurry phase occurs more rapidly than in the solid phase, but capital costs are relatively high. Figure 6-2 presents two possible design scenarios. Model Design #1 includes two bioreactors sized to handle batches of 2300 cubic yards. Two reactors are specified under the assumption that the volume to be treated is doubled by the water added to form a slurry consistency. Hence, a greater capacity would be required than that for landfarming; however, but treatment would be accomplished in a shorter time as the cycle duration is estimated to be only four to five weeks. Total treatment duration would then be two to three years.

6.2.3 Soil Washing

Soil washing is used to treat contaminants by supplying mechanical energy and water to liberate contaminants from sediment particles, thus separating the more highly contaminated fines from the coarser particles. The fines are further treated with polymers or surfactants, and mechanically agitated to remove contaminants. Soil washing is a well-demonstrated process that separates contaminants from sediments rather than destroying those contaminants. Large quantities of wastewater are generated and must subsequently be treated. Figure 6-3 presents model design parameters. A typical system, sized to treat 40 cubic yards of sediment per hour, would treat all of the sediments in only three to four months. The processes and equipment used vary widely by vendor. As an example, a more detailed schematic diagram of the process used by one vendor is provided in the vendor literature in Appendix D.

Figure 6-2
Slurry Phase Biological Treatment
Process and Equipment Information
(Alternative 3 and Alternative 5)
(Page 1 of 2)

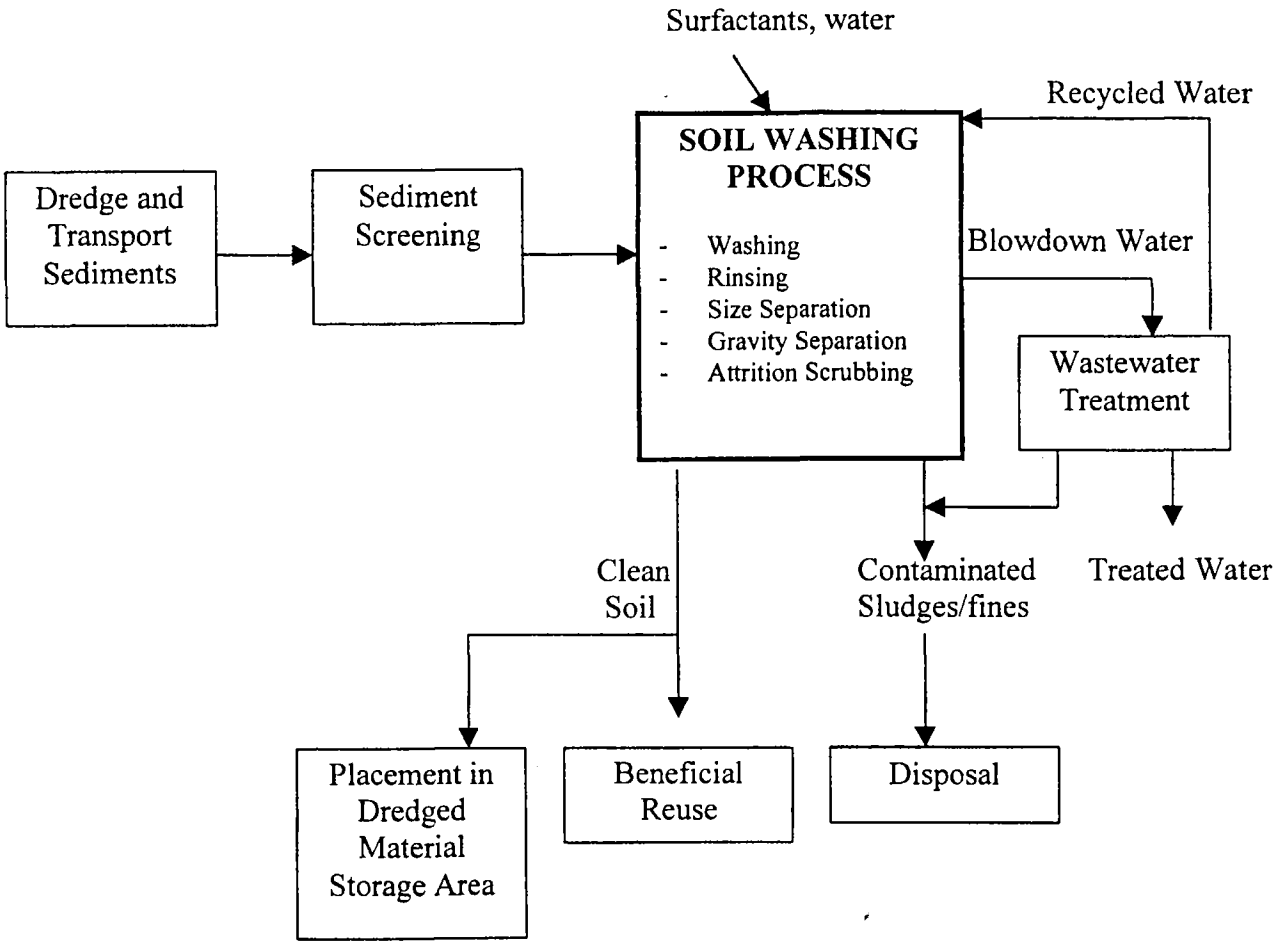


Model Design #1 Parameters:

- Footprint of each reactor: 60' x 170'
- Number of reactors: 2
- Total volume of slurry: 120,000 CY (assume that mechanical dredging results in 50% as solids; i.e., total volume to be treated is doubled)
- Volume of sediment treated per batch: 2300 CY
- Total area required: 360' x 500'
- Cycle duration: 4-5 weeks
- Total treatment duration: 2-3 years

Note: Design parameters are based on preliminary assumptions and are subject to revision at the design stage, during which the technology would be demonstrated through further testing under project-specific conditions (e.g., field demonstrations, pilot tests).

Figure 6-3
Soil Washing
Process and Equipment Information
(Alternative 4)



Model Design Parameters:
- Total volume of sediment: 60,000 CY
- Capacity of treatment system: 40 CY/hr
- Total treatment duration: 3-4 months

Note: Design parameters are based on preliminary assumptions and are subject to revision at the design stage, during which the technology would be demonstrated through further testing under project-specific conditions (e g., field demonstrations, pilot tests).

6.3 COMPARATIVE ANALYSIS MATRIX

The comparative analysis of the sediment treatment alternatives, presented in Table 6-1, evaluated the remedial alternatives against each of the seven evaluation criteria. Compliance with ARARs Analysis, one of the evaluation criteria, pertains to components of each alternative and is presented as Appendix E.

6.4 KEY TRADEOFFS

During performance of the Feasibility Study for Scuffletown Creek, evaluation of the treatment technologies under consideration was performed based on three first-tier evaluation criteria (Effectiveness, Implementability and relative Cost), which are further supplemented by four second-tier evaluation criteria (Overall Protection of Human Health and the Environment, Compliance with ARARs, Reduction of Toxicity, Mobility, or Volume, and Stakeholder Acceptance). The following are the main conclusions of the evaluation of these technologies.

Effectiveness
Based on the treatability study results, soil washing and slurry phase treatment would be considered the more effective treatments, depending on the contaminant levels in the dredged sediments. Solid phase composting would be considered less effective, since the highest PAH removals achieved were significantly lower than for the other two technologies. However, in the assessment of effectiveness, critical items to consider are the contaminant levels in the dredged sediment (as there is natural variability in sediment composition) and the level of treatment required to meet the disposal requirements for the chosen final disposition of the treated sediments. If the PAH levels achievable by solid phase composting are acceptable for the final disposition (e.g., placement into a dredge material storage area), then solid phase composting can also be considered an effective treatment technology, particularly if longer treatment durations are acceptable. In general, it appears as if the contaminants present in the stable, aged sediments in Scuffletown Creek are not as bioavailable (and thus amenable to biodegradation) as contaminants already present in the dissolved phase (i.e., pore water). This observation lends itself to the general conclusion that slurry phase biological treatment has greater PAH reduction potential than solid phase composting.

Implementability
All three technologies under consideration have pros and cons in the implementability evaluation. Solid phase composting is easy to implement from a technical standpoint. It requires minimal equipment and moderate (periodic) labor; however, it requires substantial land area dedicated for treatment for an extended period of time. Slurry phase treatment requires design and construction of a treatment system, substantial monitoring of the process, and intensive labor. Additional equipment and/or land area may be required for separating treated sediment from the slurry and/or dewatering. However, slurry phase treatment would occur very quickly; the remediation of sediments could be accomplished in a substantially shorter time than

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL
(Page 1 of 7)

Criteria	Alternative 1 No Treatment + Disposal	Alternative 2 Landfarming (Solid Phase Composting) + Disposal	Alternative 3 Slurry Phase Biological + Disposal	Alternative 4 Soil Washing + Disposal	Alternative 5 Landfarming / Slurry Phase Biological + Disposal
Description	This alternative would involve disposal of excavated sediments without treatment. It is considered a baseline alternative for comparison with treatment alternatives.	Excavated sediments are spread in a vessel or a lined landfarm cell, where biodegradation is stimulated through aeration and the addition of bulking agents. The use of specialized composting equipment has the potential to lower the treatment duration. For example, composting tractors manufactured by Brown Bear Corporation efficiently mix, aerate, and add nutrients to the sediments. This approach may require a larger treatment cell area, and the equipment would entail high capital costs. A more detailed evaluation of costs and benefits would be performed during the preliminary design stage.	Contaminated sediments are placed in a bioreactor tank, where the material is mixed with activated sludge and moisture to form a slurry. The slurry is mixed and aerated to stimulate biodegradation. Alternatively, slurry phase biological treatment could be accomplished within a subcell of a landfarm.	Sediments are mixed with washwater and various agents such as surfactants or acids to liberate contaminants from the surfaces of sediment particles and separate out the more highly contaminated fines to reduce the volume of contaminated material. Then, the contaminated wastewater stream is treated by conventional means and/or disposed of.	This alternative combines the technologies for Alternatives 2 and 3 in parallel, using landfarming as a "pretreatment" for the most highly-contaminated sediments, and bioslurry treatment for the lesser-contaminated sediments. The same vessel could be modified in order to be used for both processes. For this evaluation, it is assumed that 25% of the material would be landfarmed and 75% would undergo bioslurry treatment.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL

Criteria	**Alternative 1** No Treatment + Disposal	**Alternative 2** Landfarming (Solid Phase Composting) + Disposal	**Alternative 3** Slurry Phase Biological + Disposal	**Alternative 4** Soil Washing + Disposal	**Alternative 5** Landfarming / Slurry Phase Biological + Disposal
Overall Protection of Human Health and the Environment	Removal of contaminated sediments would eliminate risks posed by these materials at the site and enhance ecosystem. If on-site containment is selected, an on-site landfill may have to be permitted and would be constructed to minimize risk of exposure. Potential risk of worker exposure during implementation would require appropriate health and safety precautions. In general, liability for off-site transport and disposal of contaminated material would be greater than if the material were treated or disposed on-site.	Removal of contaminated sediments from the creek would eliminate risks posed by these materials at the site and enhance ecosystem. In general, on-site treatment would reduce long-term liabilities for potential releases, exposures, or incidents associated with off-site disposal. Potential risk of worker exposure during implementation would require appropriate health and safety precautions.	Removal of contaminated sediments from the creek would eliminate risks posed by these materials at the site and enhance ecosystem. In general, on-site treatment would reduce long-term liabilities for potential releases, exposures, or incidents associated with off-site disposal. Potential risk of worker exposure during implementation would require appropriate health and safety precautions.	Removal of contaminated sediments from the creek would eliminate risks posed by these materials at the site and enhance ecosystem. In general, on-site treatment would reduce long-term liabilities for potential releases, exposures, or incidents associated with off-site disposal. Potential risk of worker exposure during implementation would require appropriate health and safety precautions.	Removal of contaminated sediments from the creek would eliminate risks posed by these materials at the site and enhance ecosystem. In general, on-site treatment would reduce long-term liabilities for potential releases, exposures, or incidents associated with off-site disposal. Potential risk of worker exposure during implementation would require appropriate health and safety precautions.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL
(Page 3 of 7)

Criteria	Alternative 1 No Treatment + Disposal	Alternative 2 Landfarming (Solid Phase Composting) + Disposal	Alternative 3 Slurry Phase Biological + Disposal	Alternative 4 Soil Washing + Disposal	Alternative 5 Landfarming / Slurry Phase Biological + Disposal
Compliance With ARARs	See Appendix E: "Compliance with ARARs Analysis"				
Effectiveness	Removal of contaminated material from the site would reduce risks posed by the material, but risks associated with contaminated material would be transferred to a permitted on-site or off-site disposal facility.	24-74% removal of PAH compounds. (Source: Foster Wheeler laboratory-scale treatability studies, December 2000). Removal efficiency somewhat unpredictable due to variability in sediment composition. The aged sediment and its relative stability do not serve to enhance the effectiveness of Solid Phase Composting.	86-99% removal of PAH compounds. (Source: Foster Wheeler laboratory-scale treatability studies, December 2000). Removal efficiency may be overstated due to extraction method used during treatability study. Removal efficiency somewhat unpredictable due to variability in sediment composition.	83-96% removal of PAH compounds. (Source: Foster Wheeler laboratory-scale treatability studies, December 2000). Offers more consistent removal rates regardless of sediment composition. Water was enhanced with proprietary non-toxic surfactant to attain high removal rates.	Up to 74% removal of PAH compounds through landfarming of highly-contaminated material; up to 99% removal through slurry phase treatment of average material. (Source: Foster Wheeler laboratory-scale treatability studies, December 2000). Removal efficiency somewhat unpredictable due to variability in sediment composition.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL
(Page 4 of 7)

Criteria	**Alternative 1** No Treatment + Disposal	**Alternative 2** Landfarming (Solid Phase Composting) + Disposal	**Alternative 3** Slurry Phase Biological + Disposal	**Alternative 4** Soil Washing + Disposal	**Alternative 5** Landfarming / Slurry Phase Biological + Disposal
Reduction of Toxicity, Mobility, or Volume	Reduction of contaminant mobility would require proper containment in on-site or off-site landfill. Volume at site would be reduced if off-site disposal option is selected. Toxicity of sediment material remains unchanged.	Toxicity would be reduced in material treated to landfill or backfill standards. Treatment to backfill standards would involve greater reduction of contaminants than treating to landfill standards. Volume of material could increase significantly due to use of bulking agents to treat sediment. Volume at site would be reduced if off-site disposal option is selected. Mobility of contaminants would be largely eliminated through treatment.	Toxicity would be reduced in material treated to landfill or backfill standards. Treatment to backfill standards would involve greater reduction of contaminants than treating to landfill standards. Volume would not increase significantly since dredged material could be treated "as is". Volume at site would be reduced if off-site disposal option is selected. Mobility of contaminants would be largely eliminated through treatment.	Toxicity in treated material would be greatly reduced through transfer into liquid phase. Treatment would only be required for a contaminated fraction of the material, while larger volume of coarse-grained sediments may be returned to site as clean. However, a large volume of wastewater would be generated. Mobility of contaminants would be largely eliminated through effective wastewater treatment and disposal of residuals.	Toxicity would be reduced in material treated to landfill or backfill standards. Treatment to backfill standards would involve greater reduction of contaminants than treating to landfill standards. Volume of material subjected to solid phase composting could increase significantly due to use of bulking agents to treat sediment. Volume at site would be reduced if off-site disposal options are selected. Mobility of contaminants would be largely eliminated through treatment.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL
(Page 5 of 7)

Criteria	**Alternative 1** No Treatment + Disposal	**Alternative 2** Landfarming (Solid Phase Composting) + Disposal	**Alternative 3** Slurry Phase Biological + Disposal	**Alternative 4** Soil Washing + Disposal	**Alternative 5** Landfarming / Slurry Phase Biological + Disposal
Implementability	Need local personnel, equipment, and disposal facilities. Represents the most rapid alternative.	Need local property for placement of treatment cell; as well as local personnel, equipment, and disposal facilities. Easily implemented, requires minimal labor and equipment for construction, with moderate labor for operation and maintenance. Requires large amount of space for extended period to house treatment cell. Dewatering may be required as a pretreatment. May require long treatment cycles.	Need local property for placement of plant or treatment cell; as well as local personnel, equipment, and disposal facilities. Labor, equipment, and monitoring requirements to build and operate plant or modified treatment cell could be extensive. Treatment could be completed in relatively brief period. Additional equipment and land area may be required for separation and/or dewatering.	Need local property for placement of treatment facility; as well as local personnel, equipment, and disposal facilities. Treatment system must be designed and constructed. Labor and equipment requirements to build and operate plant could be extensive. Treatment could be completed in relatively brief period. Contaminants would not be degraded, but transferred to liquid phase, which would require subsequent treatment and/or disposal.	Need local property for placement of plant or treatment cell; as well as local personnel, equipment, and disposal facilities. Equipment for both processes could be housed within the same vessel or landfarm. Treatment could be relatively rapid for slurry phase biological system. Additional equipment and land area may be required for landfarming, as well as separation and/or dewatering for the slurry phase biological system.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL
(Page 6 of 7)

Criteria	**Alternative 1** No Treatment + Disposal	**Alternative 2** Landfarming (Solid Phase Composting) + Disposal	**Alternative 3** Slurry Phase Biological + Disposal	**Alternative 4** Soil Washing + Disposal	**Alternative 5** Landfarming / Slurry Phase Biological + Disposal
Unit Costs (Capital and O & M, including dredging, treatment, and disposal)	$32 – 65 / CY Estimated cost does not include waste characterization analysis or sediment stabilization/bulking costs, which would also increase the volume to be disposed. All materials are assumed non-hazardous; however, the sediments are heterogeneous and potential exists for individual batches to be characterized as hazardous, which would increase disposal fees.	$65 – 100 / CY Overall unit cost could be reduced to as low as $54/CY if part or all of the material is treated to clean backfill standards, thereby eliminating disposal costs. Comparable cost savings may be realized if the final material could be placed into a dredged material storage area (e.g., Higgerson Buchanan), rather than disposed of in a permitted landfill.	$180 – 275 / CY Overall unit cost could be reduced to as low as $170/CY if part or all of the material is treated to clean backfill standards, thereby eliminating some disposal costs. Comparable cost savings may be realized if the final material could be placed into a dredged material storage area (e.g., Higgerson Buchanan), rather than disposed of in a permitted landfill.	$110 – 190 / CY Overall unit cost could be reduced to as low as $95/CY if part or all of the material is treated to clean backfill standards, thereby eliminating some disposal costs. Also, cost could be reduced if wastewater could be discharged back into the creek. Comparable cost savings may be realized if the final material could be placed into a dredged material storage area (e.g., Higgerson Buchanan), rather than disposed of in a permitted landfill.	$150 – 230 / CY Overall unit cost could be reduced to as low as $140/CY if part or all of the material is treated to clean backfill standards, thereby eliminating some disposal costs. Comparable cost savings may be realized if the final material could be placed into a dredged material storage area (e.g., Higgerson Buchanan), rather than disposed of in a permitted landfill.

TABLE 6-1
NORFOLK DISTRICT USACE
SCUFFLETOWN CREEK
SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES FOR TREATMENT AND DISPOSAL

Criteria	Alternative 1 No Treatment + Disposal	Alternative 2 Landfarming (Solid Phase Composting) + Disposal	Alternative 3 Slurry Phase Biological + Disposal	Alternative 4 Soil Washing + Disposal	Alternative 5 Landfarming / Slurry Phase Biological + Disposal
Stakeholder Acceptance	Stakeholders may not respond as positively to restoration not involving proactive reduction of long-term liabilities associated with the final waste disposition. Also, on-site beneficial reuse of material maximizes program benefits.	Destruction of contaminants through natural biological processes is an environmentally friendly approach and lends itself to beneficial reuse. However, longer time periods may be required. Would positively impact the local/regional economy due to effective utilization of local/regional sources of labor, equipment, materials, and land.	Destruction of contaminants through natural biological processes is an environmentally friendly approach and lends itself to beneficial reuse. However, longer time periods may be required. Would positively impact the local/regional economy due to effective utilization of local/regional sources of labor, equipment, materials, and land.	Labor, equipment, and monitoring requirements for soil washing are elaborate. Contaminants are not destroyed; transferring them from sediment to water that requires disposal may not be viewed as environmentally friendly, although wastewater could be treated by conventional methods. Would positively impact the local/regional economy due to effective utilization of local/regional sources of labor, equipment, materials, and land.	Labor, equipment, and monitoring requirements for bioslurry treatment system are elaborate. Destruction of contaminants through natural biological processes is an environmentally friendly approach and lends itself to beneficial reuse. However, longer time periods may be required. Would positively impact the local/regional economy due to effective utilization of local/regional sources of labor, equipment, materials, and land.

Legend of Alternatives with Respect to Disposal Options

Alternative 1:
No Treatment + Disposal
Where Disposal =
Disposal in Landfill Constructed On-Site
Or Off-Site Disposal in Landfill
Or On- or Off-Site Beneficial Reuse as Backfill of the least contaminated material. Possible backfill sites include the Craney Island Dredged Material Management Area or the Higgerson Buchanan Site. Backfill standards have not been established for these sites, so all or part of the dredged sediments may be acceptable for disposal.

Legend of Alternatives with Respect to Disposal Options (cont'd)

Alternative 2:
Landfarming + Disposal
Where Disposal =
Disposal in Landfill Constructed On-Site
Or Off-Site Disposal in Landfill
Or On- or Off-Site Beneficial Reuse as Backfill of the "cleanest" treated material. Possible backfill sites include the Craney Island Dredged Material Management Area or the Higgerson Buchanan Site. Backfill standards have not been established for these sites, so all or part of the dredged sediments may be acceptable for disposal.

Alternative 3:
Slurry Phase Biological Treatment + Disposal
Where Disposal =
Disposal in Landfill Constructed On-Site
Or Off-Site Disposal in Landfill
Or On- or Off-Site Beneficial Reuse as Backfill of the "cleanest" treated material. Possible backfill sites include the Craney Island Dredged Material Management Area or the Higgerson Buchanan Site. Backfill standards have not been established for these sites, so all or part of the dredged sediments may be acceptable for disposal.

Alternative 4:
Soil Washing + Disposal
Where Disposal =
Disposal in Landfill Constructed On-Site
Or Off-Site Disposal in Landfill
Or On- or Off-Site Beneficial Reuse as Backfill of the "cleanest" treated material. Possible backfill sites include the Craney Island Dredged Material Management Area or the Higgerson Buchanan Site. Backfill standards have not been established for these sites, so all or part of the dredged sediments may be acceptable for disposal.

Note that soil washing would result in a large volume (50-70% or original volume) as "clean" sediment, with the contaminants concentrated in the remaining residual of fines. The large clean volume would be especially suited to beneficial reuse as backfill.

Alternative 5:
Landfarming/Slurry Phase Biological Treatment + Disposal
Where Disposal =
Disposal in Landfill Constructed On-Site
Or Off-Site Disposal in Landfill
Or On- or Off-Site Beneficial Reuse as Backfill of the "cleanest" treated material. Possible backfill sites include the Craney Island Dredged Material Management Area or the Higgerson Buchanan Site. Backfill standards have not been established for these sites, so all or part of the dredged sediments may be acceptable for disposal.

Note that the "cleanest" treated material would be the sediments treated by the bioslurry process. The landfarmed material would be the sediments containing the highest initial concentrations and would likely be landfilled after treatment.

Assumptions:

- Costs include dredging and transport of sediments to treatment or disposal area (assumed to be $20 per cubic yard. Source: USACE Norfolk's "Formulation Analysis Notebook for Elizabeth River Basin, Virginia, dated September 2000).
- Costs include disposal of treated material in constructed on-site landfill or off-site landfill. (Range of costs reflects variation in potential disposal costs)
- One cubic yard of sediment is assumed to have a mass of 1.3 tons, based on conditions at a large sediment remediation project performed by Foster Wheeler in the same geographic region.
- Disposal of residual waste generated during treatment processes is not included in cost estimates. Amounts of residual waste (e.g., wastewater) generated from treatment processes can not be quantified at pre-design stage.

composting. Also, the complexities associated with slurry phase treatment could be greatly reduced by accomplishing treatment within a modified landfarm treatment cell. Soil washing, like slurry phase treatment, would require substantial equipment and labor, but could also be completed much more quickly than composting. Soil washing has the added disadvantage of not providing any biological degradation of contaminants, but merely transferring them from the sediment to the liquid phase, which would require separate treatment or disposal. The overall volume of sediments to be dredged and the feasibility of segregating sediments of varying contaminant concentrations are critical factors in evaluating and comparing the implementability of these technologies.

Cost

Based on preliminary engineering estimates, composting would be the lowest cost treatment, soil washing would be the higher cost, and slurry phase biological treatment would be the highest cost. However, performance of slurry phase biotreatment in a landfarm cell could greatly reduce the cost, perhaps to a level comparable to solid phase composting. Several factors will affect the unit costs of the three treatment technologies. The total volume of sediment to be treated and the contaminant levels that must be achieved for final disposition of the treated sediment are critical factors in determining the ultimate cost for each technology. The anticipated contaminant levels in the dredged sediment are also critical, since additional costs to segregate sediments with differing contaminant levels may easily be offset by a smaller volume of sediment requiring treatment prior to disposal. In addition, consideration may be given to using a lower cost treatment for some portion of the removed sediment. Finally, the unit treatment cost could be reduced if project stakeholders elect to use the treatment facility for future work involving the additional sites being evaluated for sediment remediation.

7.0 SUMMARY OF CONCLUSIONS

Based on the findings of the treatability studies, all of the three treatment technologies tested would be effective for potentially reducing PAH levels by significant amounts in the sediment. Hence, the most suitable method of treatment may be determined based on evaluation of a number of other factors that are valued by project stakeholders, such as economic and implementation considerations, as well as anticipated benefit to the environment. This section summarizes the major findings of the Feasibility Investigation which should be considered by project stakeholders in selecting the optimal remedial alternative.

The easiest alternative to implement is landfarming, while the more complex alternatives are slurry phase biological treatment and soil washing. If time is not a major constraint, landfarming is a desirable option. While the contaminant degradation occurs at a slower rate, a greater removal percentage may eventually be attained. In addition, capital costs are greatly reduced due to the simplicity of landfarming, which has lower equipment requirements. However, the effectiveness in removing contaminants was demonstrated to be more consistent in the bioslurry and soil washing processes during the bench-scale treatability testing.

Generally, soil washing would require the highest level of capital investment due to the requirement for a dedicated treatment plant. Also, unlike the biological treatment options, it does not destroy contaminants, but, in effect, transfers them from sediment to water. This would create an additional, potentially large waste water stream that would require further treatment.

There are a number of implementation approaches to be considered that may attain substantial cost reductions. One would be construction of the treatment facility at a dredged material management site such as Higgerson Buchanan. This option would be advantageous because it is close in proximity to the Scuffletown Creek site; there is land available for the staging, treatment, and placement of sediments; and, since it is already established as a receiving facility for dredged materials, there would be reduced mobilization requirements for transport and handling of the sediments. Another approach that may reduce costs would be to treat sediments to a "pre-treatment" extent to permit final disposition of material in a dredged material management site, as opposed to doing full treatment to use material as clean backfill.

8.0 RECOMMENDATIONS

In consideration of the salient features of each remedial technology that have been identified both individually and relative to each other as a result of the Feasibility Investigation, recommendations can be made regarding the most suitable technology to retain for preliminary design. The preliminary design phase will accomplish the following:

- Precisely define process and construction parameters.
- Develop engineering cost estimates for process and end-use variations.

Table 8-1 presents a ranking of the three treatment technologies against the three first-tier criteria. This will assist project stakeholders in making a decision based on the criteria that are most highly valued. In two cases, there is a "tie" between slurry phase biological treatment and soil washing, due to the fact that either could be preferred based on decisions in approach that would be made during the preliminary design phase.

Table 8-1
Ranking of Treatment Technologies vs. First-Tier Criteria

EFFECTIVENESS	1. Slurry Phase Biological or Soil Washing 2. Landfarming
IMPLEMENTABILITY	1. Landfarming 2. Slurry Phase Biological or Soil Washing
COST	1. Landfarming 2. Soil Washing 3. Slurry Phase Biological

NOTE: 1 = BEST, 3 = WORST

This evaluation tool points to landfarming as the preferred treatment alternative, with its highest ranking in two categories, Implementability and Cost. Although its effectiveness appeared to lag behind the other technologies during the treatability testing, an acceptable level of effectiveness may be attained merely as a function of time; if rapid treatment is not a high priority, landfarming would likely succeed in reaching the removal requirements suitable for the final disposition/end use of the material. Its relatively simple implementability and cost-effectiveness indicate that landfarming is the most favorable choice for treatment of Scuffletown Creek sediment.

Note that, regardless of the technology selected, further demonstration may be advisable prior to full-scale implementation. This could be accomplished in the field on a pilot scale, perhaps through cooperation with technology vendors.

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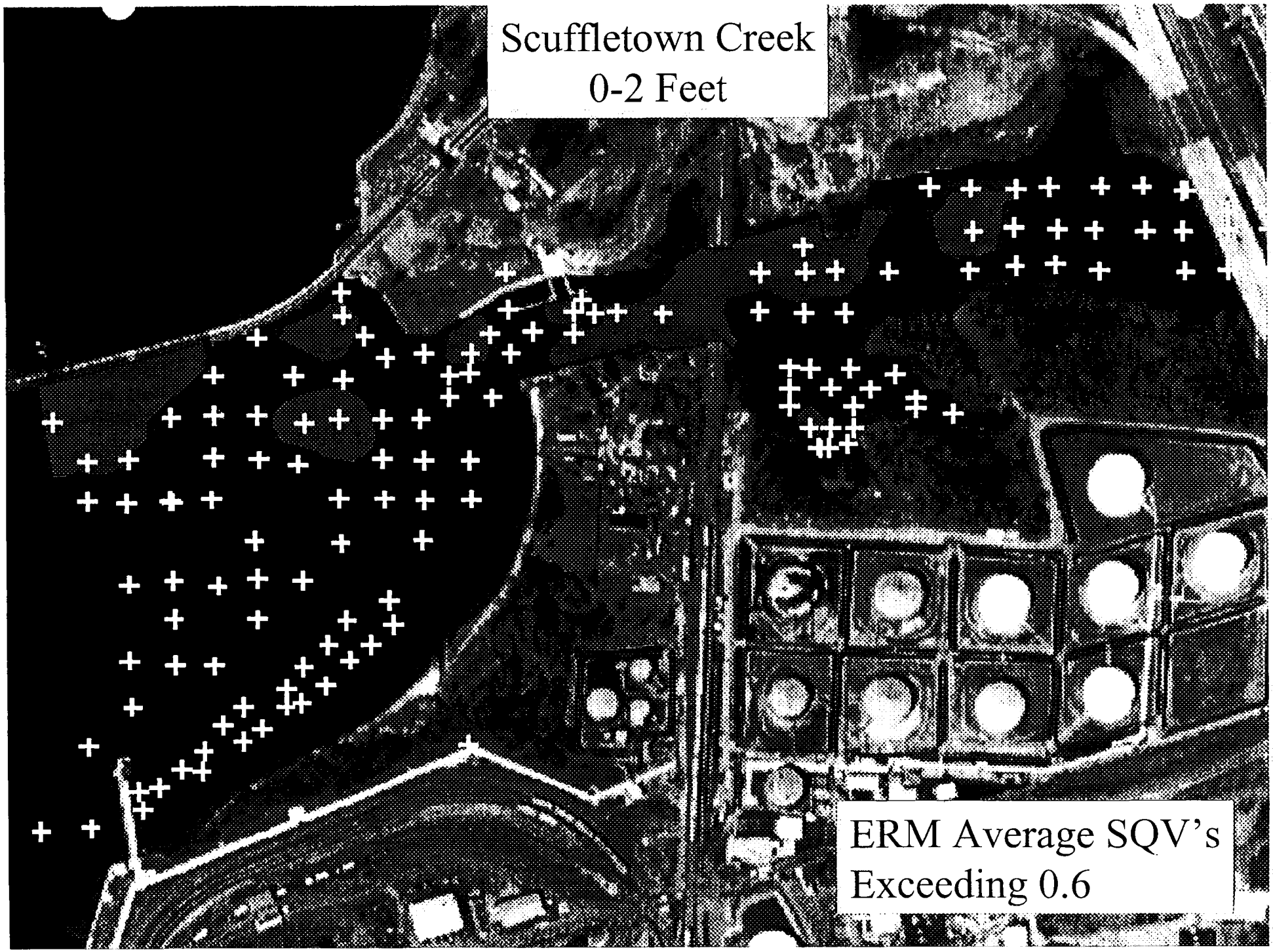
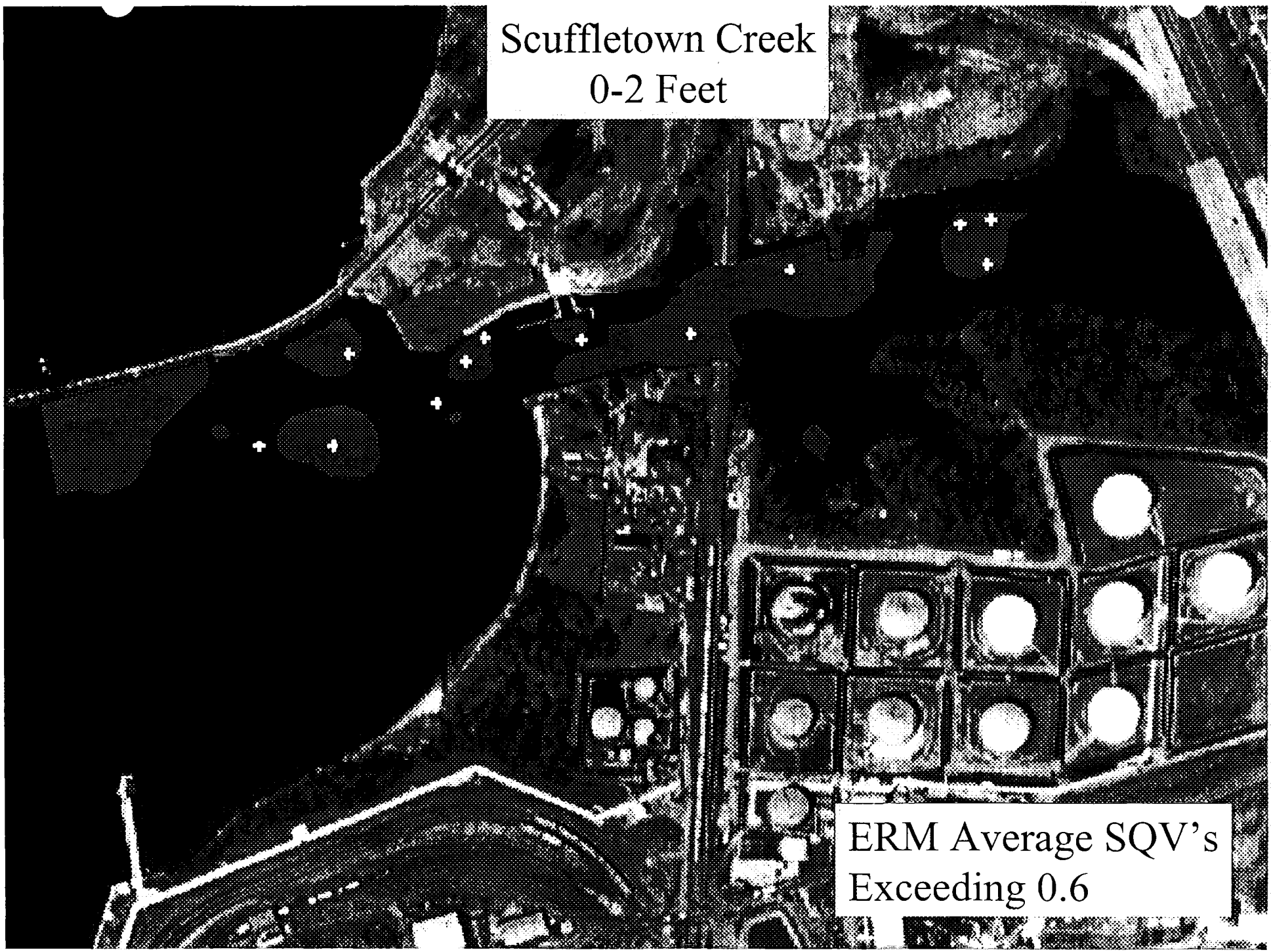
USEPA. *Treatment Technology Overview.* http://www.epareachit.org.

ATTACHMENT E

GROUNDWATER MODELING SYSTEM (GMS) CONTOURS


Scuffletown Creek
0-2 Feet
ERM Average SQV's
Exceeding 0.6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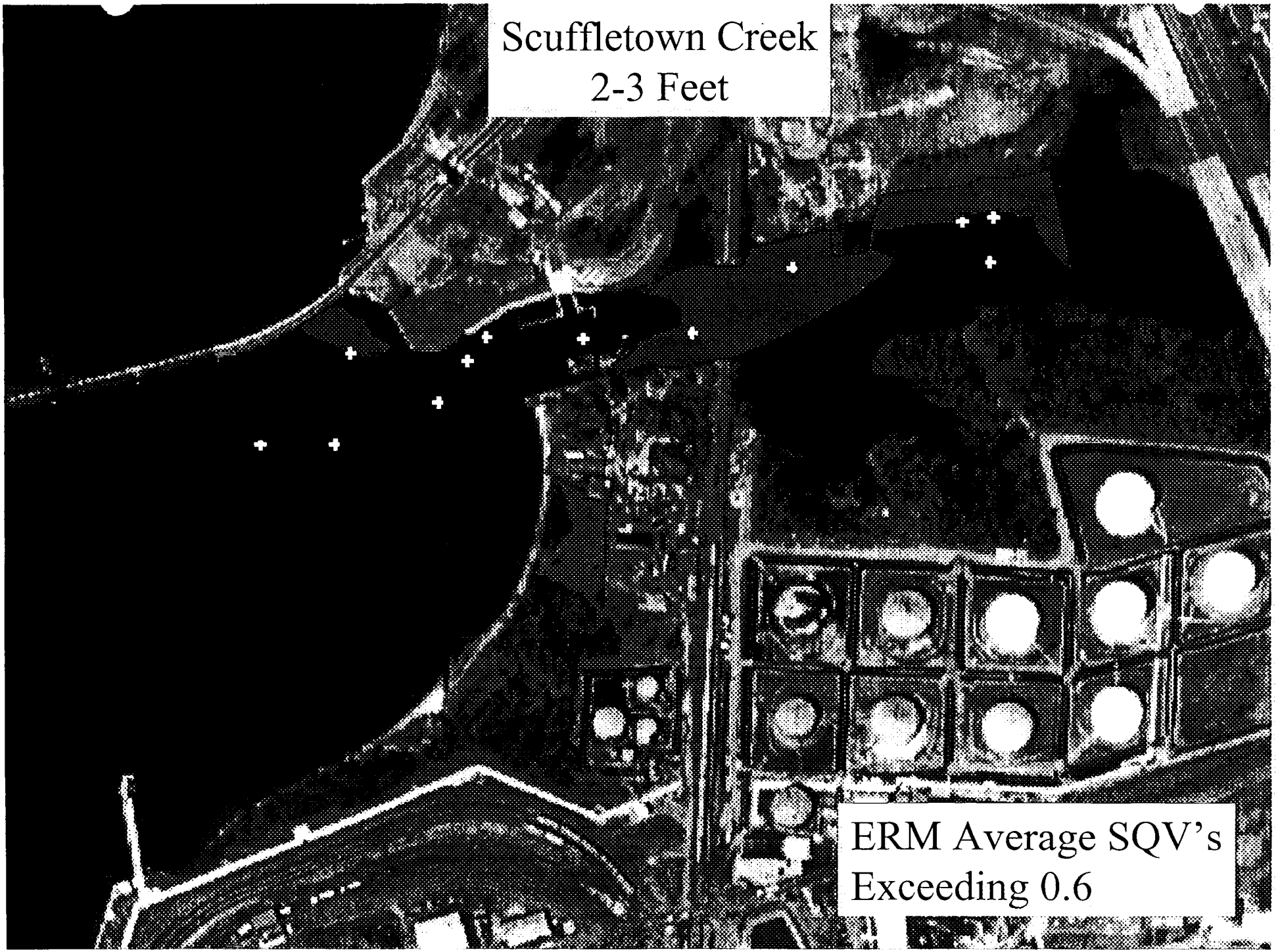
ERM Average SQV's
Exceeding 0.6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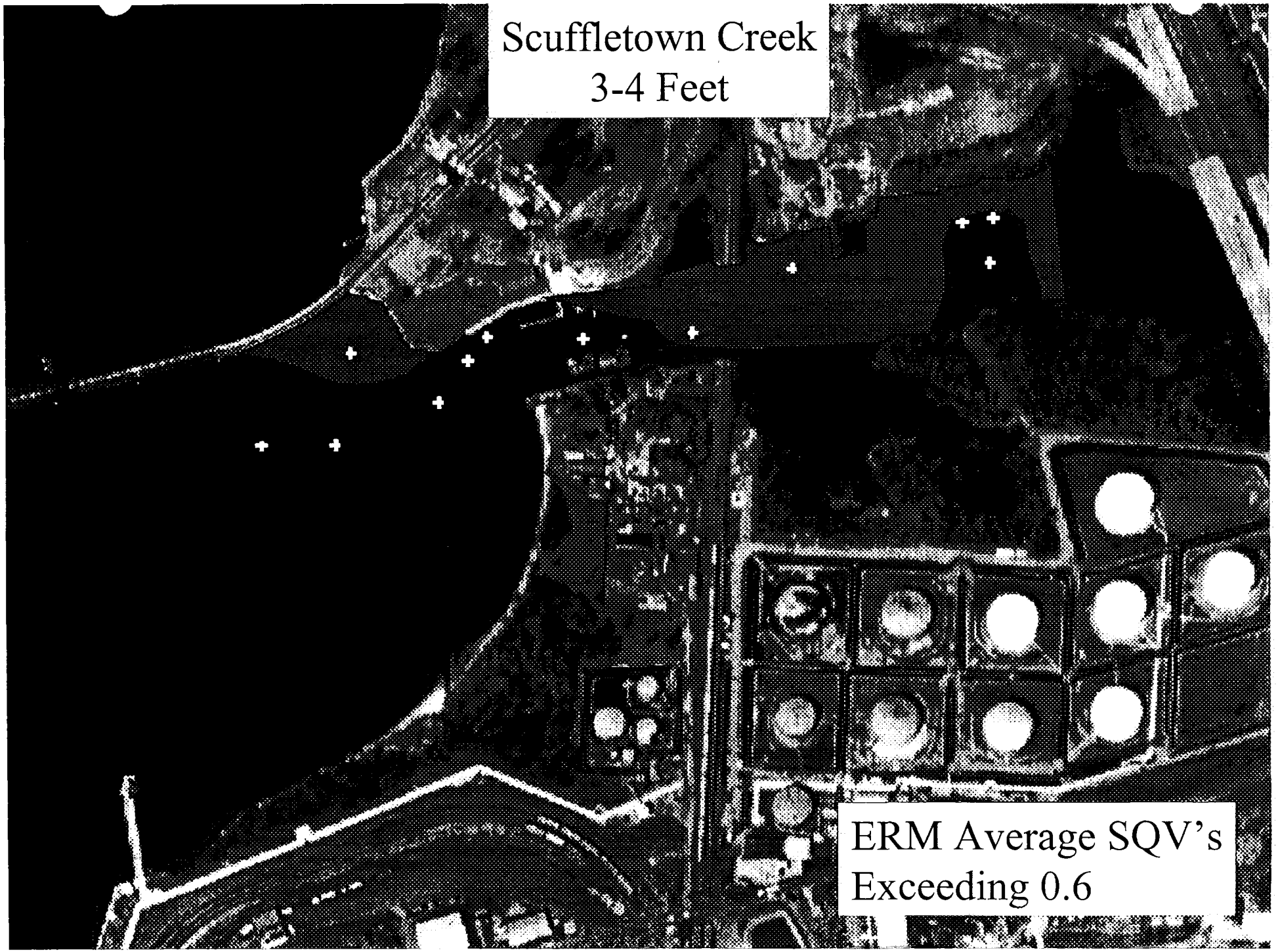
2-3 Feet
ERM Average SQV's
Exceeding 0.6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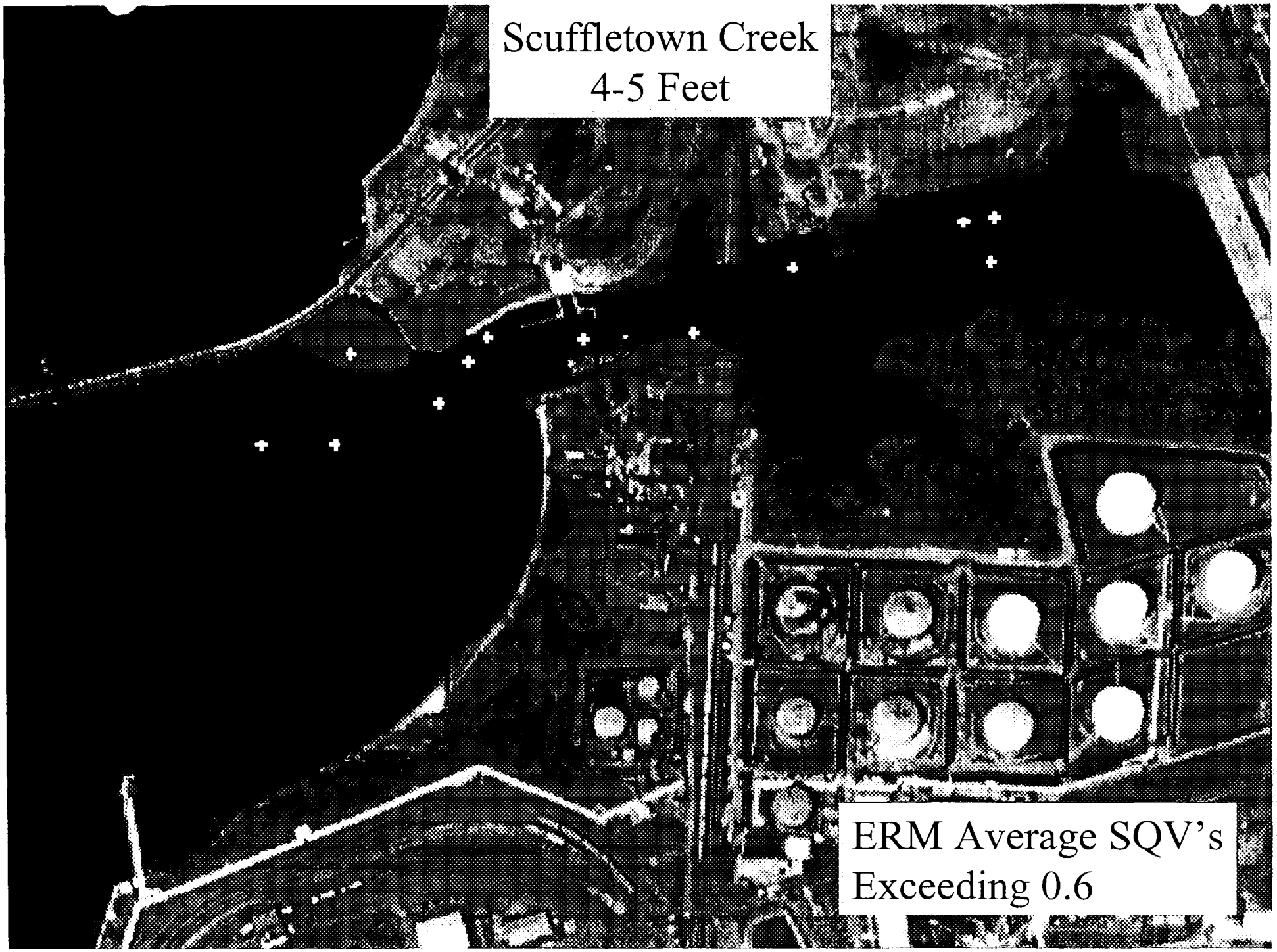
3-4 Feet
ERM Average SQV's
Exceeding 0.6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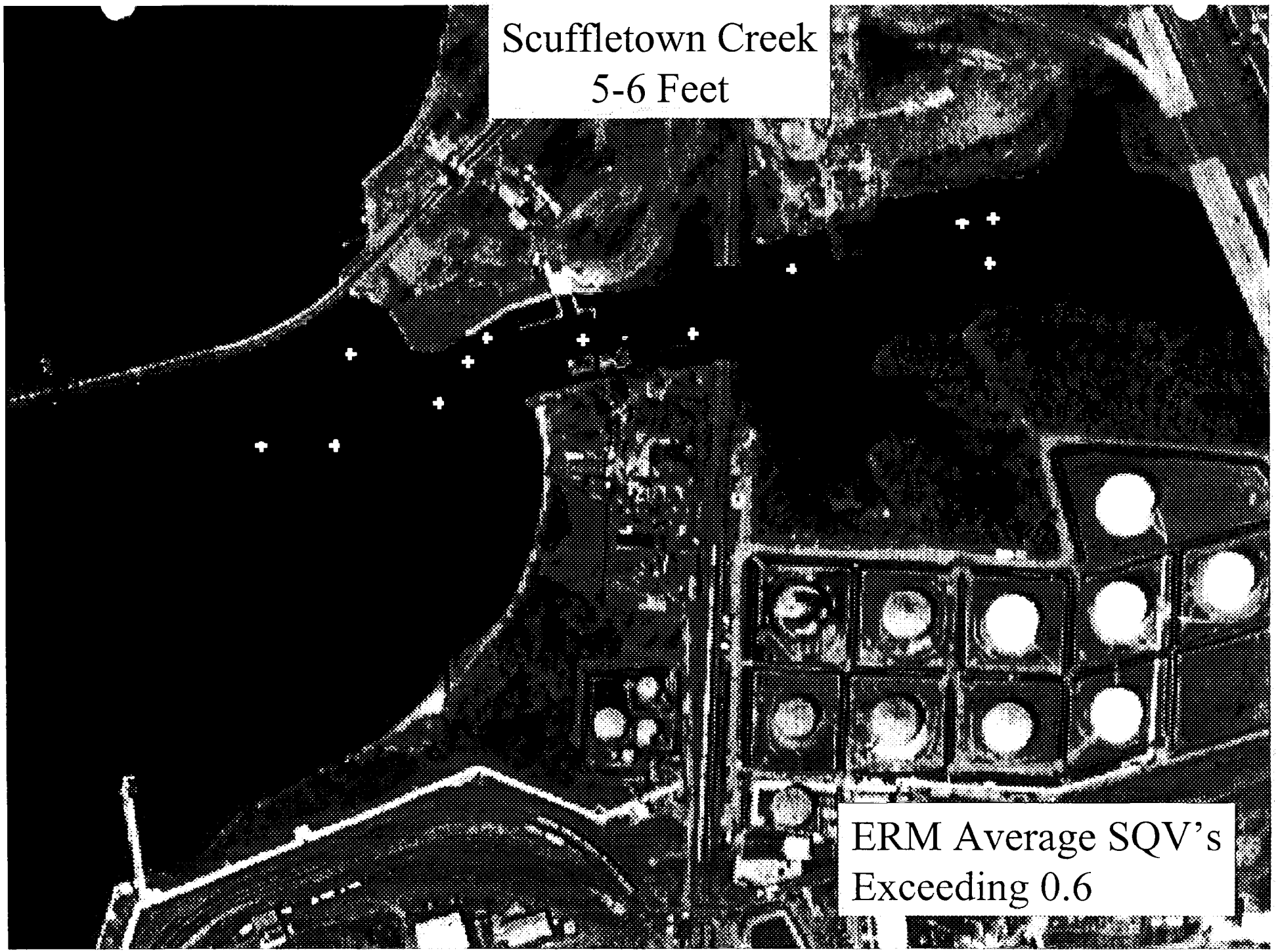
ERM Average SQV's
Exceeding 0.6


Scuffletown Creek
5-6 Feet
ERM Average SQV's
Exceeding 0.6

ATTACHMENT F

TOXICITY TEST RESULTS

Toxicity Testing
Old Dominion University
Applied Marine Research Laboratory
and
U.S. Environmental Protection Agency

OLD DOMINION UNIVERSITY

Applied Marine Research Laboratory
College of Sciences
Norfolk, Virginia 23529-0456

AN ASSESSMENT OF AMBIENT TOXICITY IN SEDIMENT FROM THREE STRATA IN THE ELIZABETH RIVER, VIRGINIA

Draft Final Report

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AMRL Technical Report No.

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AN ASSESSMENT OF AMBIENT TOXICITY IN SEDIMENT FROM THREE STRATA IN THE ELIZABETH RIVER, VIRGINIA

ABSTRACT

Three locations in the Elizabeth River are considered candidate sites for remediation of potentially contaminated sediment. Surficial sediment from sites within Scuffletown Creek (Southern Branch), Scotts Creek (Mainstem), and in the vicinity of the Campostella Bridge (Eastern Branch) were used in sediment bioassays with estuarine fish and amphipods to assess ambient toxicity. Bioassays performed on sediments collected from these sites in October 1999 with the amphipod *Leptocheirus plumulosus* showed very little toxicity at any site, but the results were suspect since reference toxicant tests were invalid. The fish (Sheepshead Minnow *Cyprinodon variagatus*) bioassays on the same sediments were flawed and failed to provide meaningful data. Sediment from these same sites and locations were collected again in April 2000 and the bioassays were rerun. In the second round of sediment bioasssays, no statistically different acute or growth effects with either test species were observed when the strata were compared to a reference site. As the assessment of these study areas continues, comparing the results of this study with ongoing research and monitoring efforts may provide additional information about the ambient conditions within the strata.

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AN ASSESSMENT OF AMBIENT TOXICITY IN SEDIMENT FROM THREE STRATA IN THE ELIZABETH RIVER, VIRGINIA

INTRODUCTION

The Sediment Subcommittee of the Elizabeth River Study Steering Committee requested that ambient toxicity at several locations in the Elizabeth River be characterized in an effort to better understand the potential for effects to the benthos from in-place contaminants. Sediments were collected from random positions within Scuffletown Creek and Scotts Creek, as well as in the vicinity of Campostella Bridge in October, 1999 and in April, 2000. These locations are candidate sites for sediment remediation efforts and the potential for sediment toxicity is one factor to be used in deciding if and where remediation may be necessary. Sediment toxicity is one measure of impairment where indigenous or representative and sensitive organisms are exposed to sediments under laboratory conditions. Survival of the test organisms in sediment bioassays under laboratory conditions that is statistically significant and less than the survival seen from exposure to sediments from a clean or reference area is a strong indication that the sediments may not be supporting a healthy community of bottom dwelling organisms of similar sensitivity.

The primary objective of this study was to provide data and an assessment that estimates the ambient sediment toxicity due to in-place contaminants using representative benthic organisms native to the study area exposed to these sediments under laboratory conditions. The response of the organisms to a reference sediment that was similar in physical and other characteristics to the test sediments and that was relatively free of contaminants was used to estimate the toxicity due to the presence of contaminants alone. The response to these reference sediments was the basis for evaluating the organism response to the test sediments.

The data presented in this report includes: 1) number of live amphipods at the end of 10 days of exposure to the test sediments (October, 1999 and April, 2000 sediment), successful hatching of the fish egg hatching/survival test (October, 1999 sediment), survival of fish fry and growth (April, 2000 sediment), negative controls, and reference sediments; 2) number of live organisms at the end of the exposure to a reference toxicant (positive control) and historical data (from the literature or from in-house records) for acceptable responses; and 3) particle size characteristics of the test sediment, reference sediment and negative control sediment. Ancillary data to be used in evaluating factors not related to contaminant toxicity includes pore water characteristics, particle size analyses, and organic carbon content.

METHODS

Study Area

Stratified random sampling was performed at each of the following study areas: 1) Scuffletown Creek (4 strata with 5 random sediment samples collected per stratum); 2) Scotts Creek (1 stratum with 10 random sediment samples collected); and 3) an area near the Campostella Bridge (1 stratum with 10 random sediment samples collected) (Tables 1-4). The geographic boundaries of each strata were assigned by the United States Army Corps of Engineers -Norfolk District (USACE-ND) to the study sites. The random locations within each strata were given an equal probability of being sampled. A reference site located outside of the Elizabeth River watershed (a 100 m x 100 m grid within Carters Creek, VA, 10 randomly located sediment samples, Table 1) was chosen for comparison to the conditions within the Elizabeth River, and a negative control site located within Ware River, VA (Table 1) was selected to provide quality control for the test performance. Sediment samples were collected in the study areas in October, 1999 and April 2000 at the same locations within the accuracy and precision of differential beacon GPS (DGPS). Since the variability of ambient toxicity in each strata as well as the mean toxicity within the area was of concern, the average toxicity for that area was determined using sediment toxicity tests and the range of responses to these tests.

Sediment Collection

Sediments were collected using a petite ponar grab sampler and only the upper 2cm of sediment was used in the bioassay. The surficial sediment was collected to provide an understanding of the ambient toxicity that may be occurring in this biologically active zone.

The samples were collected from a small boat after careful positioning at the sampling station using an on-board differential beacon GPS (DGPS) that allowed a 3-5 m accuracy in deploying the sediment grab sampler. A number of grabs at each station were necessary to provide sufficient quantities of surficial sediments. Frequently large pieces of plastic "trash" and shell hash prevented the grab sampler from closing when retrieved. This material was discarded and the grab was repeated until a relatively undisturbed sample was obtained. At each station, the top 2 cm of surficial sediment from each grab was pooled until sufficient material had been collected. This pooled sample was homogenized in the field and treated as a representative sample for that location. The pooled sample was split into aliquots for the toxicity tests, pore water extractions, particle size analysis and other analyses. At 20% of the stations within a stratum, duplicate samples were prepared by collecting and homogenizing surficial sediments twice using the same techniques as described above. This resulted in two unique samples (field duplicates) independently collected from the same position with care given to not collecting sediment from the same "hole" as the previous sample collected. All samples were stored on ice in a cooler while in the field. Samples for TOC and pore water analysis were stored in a locked freezer at -10^0C upon arrival at the laboratory. Bioassay and particle size analysis samples were stored in a locked refrigerator (4^0C). Strict chain-of-custody was maintained for all samples.

Toxicity Tests

The protocols for performing the toxicity tests for sediment collected in October, 1999 using the amphipod *Leptocheirus plumulosus* and Sheepshead Minnow *Cyprinodon variegatus* were modified from Methods for Assessing the Toxicity of Sediment-associated Contaminants with Estuarine and Marine Amphipods (EPA/600/R-94/025, USEPA, 1994), "Standard Guide for Conducting 10-day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods" (ASTM, 1992: E 1367-92) and "Standard Guide for Conducting Early Life-Stage Toxicity Tests with Fishes" (ASTM, 1992: E 1241-92). These protocols are routinely used in the USEPA Chesapeake Bay Ambient Toxicity Assessment Program (See Appendix A).

For the acute (10 day) sediment bioassays performed on sediments collected in April, 2000, the procedures followed guidance provided in USEPA Test Method 100.4 (USEPA, 1994). A summary of the methods are provided in Appendix B for the toxicity tests performed with the amphipod *Leptocheirus plumulosus* and Sheepshead Minnow *Cyprinodon variegatus*. Modifications to the method necessary to perform the Sheepshead Minnow bioassay as summarized as well.

Before initiating the toxicity tests, sediments from each site were press sieved through a 500 µm screen to remove predators, organisms similar to the test species, and foreign objects. The sediments were bedded in the test chambers with overlying clean water of the appropriate salinity and the sediments were allowed to settle for 48 hours prior to beginning the tests. For the October, 1999 bioassays, the amphipods were approximately 2-4 mm in length and the Sheepshead Minnow eggs were fertilized within 24 hours of test initiation. Amphipods were collected from the culture tank by sieving the sediments through a 710 µm mesh and the organisms retained on a 425 µm mesh were placed into clean culture water. By visual inspection, amphipods larger than 4 mm were removed before random selection for the test treatments. The exposure period for both species was 10 days with daily measurements of water quality conditions and observations of test organism responses. Tube construction by the amphipods was noted but not scored because of the difficultly in enumerating tube openings not adjacent to the container wall. Emergence of the amphipods was not detected during the exposure period. Daily counts of viable eggs, number of individuals hatched, and number of live fry in the Sheepshead Minnow test chambers were recorded. The overlying water was not renewed and the test organisms were not fed during the test. The test was conducted at 25^{0}C and the lights in the test chamber were left on for the duration of the test. Mortality was inferred by counting the surviving organisms and subtracting that number from the initial number of animals placed in the test replicate at test initiation. At day 10 of the toxicity test, the sediment in the amphipod tests was sieved and the number of surviving organisms was observed and recorded.

The methods used for the toxicity tests performed on sediments collected in April, 2000 are provided in Appendices A and B. The most significant difference between the two studies was that the later sediments were tested using Sheepshead Minnow larvae rather than beginning the test with fertilized eggs as was performed in the October, 1999 sediments.

Statistical Analysis

Survival and weight data were tested for assumptions of normality and equality of variances using Shapiro-Wilk's and Bartlett's tests, respectively. Parameters violating these assumptions were transformed to arc-sine values, ranks and normalized rankits and then retested for these assumptions. If the original or transformed data met the assumptions, an ANOVA was used to test for significant differences in mean survival and weight between stations. *A posteriori* pairwise comparisons of mean survival between the test and reference sites were conducted using the Bonferroni T-test for unequal sample sizes. If transformed data did not meet the assumptions of the parametric tests, a Kruskal-Wallis test was used to test for significant differences in median ranks between stations and *a posteriori* pairwise comparisons between the test and reference sites were made using Wilcoxon's Rank-Sum test. Any test sites that had significantly lower survival than the reference site were considered to be impaired.

For the April 2000 study, sublethal effects were assessed by comparing the weights of the amphipod and fish larvae. The same general statistical protocol for testing assumptions and comparing test sites with the reference site were conducted for the weight data. In order to eliminate any potential bias due to differential survival, only those test sites not exhibiting significantly lower survival were analyzed for sublethal effects.

RESULTS

The complete results of the statistical analysis of the bioassay data are presented in Tables 9 through 20. Not all tables are referenced in this report, but the tables are provided to facilitate future analyses of the data.

October, 1999: Embryo-larval fish 10-day sediment bioassay

The Sheepshead minnow (*Cyprinodon variegatus*) embryo-larval bioassays were compromised by a fungal outbreak in the test chambers. The results (Table 5) did not reveal any apparent differences using descriptive statistics and the results did not satisfy the requirements of subsequent attempts to perform the statistical analyses. The data were invalid since the reference toxicant tests (Table 6) failed to meet the data quality indicators for a successful test and the survival in the control and reference treatments were less than expected. The data presented in Table 5 were not used in this assessment.

October, 1999: Amphipod 10-day sediment bioassay

Nearly all individuals survived in the reference and control sediments (Table 7) and survival in the test treatments was remarkably high. The reference toxicant test with the amphipod (*Leptocheirus plumulosus*) failed to provide a valid results (Table 8). However, the negative sediment control had the highest survival of all treatments suggesting that the performance of the test may have been acceptable (Figure 1). The lowest mean survival was seen with sediments collected from Scuffletown Creek (SCFTLT1 =86% and SCFLT3 = 87%)

and the Campostella (CPSTL1 = 88%) site. The results suggests that, when randomly located samples are employed, the toxicity of the strata is low when assessed by this protocol and test species. There was no statistically significant difference ($p < 0.05$) in mean ranks of *L. plumulosus* survival between sites (Table 16a) and there were no significant differences between test and reference sites with respect to ranks of *L. plumulosus* survival (Table 16b)

A graphical comparison of the mean percent survival and standard errors suggests that there is a difference (Figure 1) between the reference site and the northwest stratum (SCFLT3) of Scuffletown Creek and the northeast stratum (SCFLT1) had mean survival similar to SCFLT3 but because of the range of survival (70% to 95%) it is difficult to claim it is different from the reference condition. However, in no case was the survival of the amphipods less than 80% of the reference or control sediment responses, an approach that has often been used to determine if a statistically significant difference is likely to be ecologically significant as well. The "80%" rule has been applied in EMAP studies to screen for false positives, but the approach is controversial and may not reflect population level effects.

The amphipods exposed to the reference sediment (CCR = Carters Creek reference sediment) bioassays had a mean survival less than the controls, but this was driven by one out of the ten random samples collected from within the 100m x 100m site in the Creek having only 13 out of 20 survivors. All other random samples collected from the reference site had survival equal to or greater than 90% with 6 samples having no mortality. If this sample could be rejected, although there is no adequate justification to do so, the mean survival and variability would be very similar to the control sediment. Regardless, there was no significant difference in mean ranks of amphipod survival between the control and reference sites ($T = -0.7109$, $p = 0.4809$).

At the end of the exposure period, the surviving amphipods were transferred to a container with clean sediment and the number of individuals that remained in the water column or on the surface of the sediments after one hour was scored. All of the individual amphipods in every treatment, reference and control immediately burrowed into the sediment and there were no indications that the survivors were impaired in their ability to burrow.

April, 2000: Larval fish 10-day sediment bioassay

The lowest survival in any test chamber for the Sheepshead Minnow bioassay was 85% and the lowest mean survival of any strata was 95.5% for the southwest strata in Scuffletown Creek (SCFLT4). The results (Table 21) clearly shows very little acute toxicity throughout the study area using this test organism. Survival when exposed to the reference and control sediment was greater than 90% in all test chambers with the exception of 1 random sample collected within the control site that had only 85% survival. There was no significant differences in median ranks of *C. variegatus* survival between sites (Table 19a) and there were no significant differences in ranks of *C. variegatus* survival between test and references sites (Table 19b). Although there was a significant difference in mean *C. variegatus* weights between sites (Table

20a), mean *C. variegatus* weights for all test sites were not significantly lower than the mean weight for the reference site (Table 20b).

April, 2000: Amphipod 10-day sediment bioassay

The control sediment (WRC) survival for the amphipod was greater than 85% in all replicates and the mean control survival was 91% (Table 23). Mean survival for the reference sediment (CCR) was 85.5%. The lower than expected survival for the reference sediment was driven by one of the random samples from this site having only 50% survival. If this random sample could be rejected, the mean survival would be approximately 89%. Unfortunately, there is no sound reason for rejecting this sample at this time. Mean survival in the northeast strata (SCFLT1), mid reach strata (SCFLT2), and the southwest strata (SCFLT4) of Scuffletown Creek, based on a visual inspection of Figure 2, appeared to be better than mean survival in the reference sediment.

There was no statistically significant difference in mean arc-sine transformed *L. plumulosus* survival between sites (Table 17a) and there were no significant differences between test and reference sites with respect to ranks of *L. plumulosus* survival (Table 17b). There was a significant difference in mean normalized rankits of *L. plumulosus* weight between sites (Table 18a) but the *a posteriori* pairwise comparisons indicated that mean normalized rankits of *L. plumulosus* weight for all test sites were not significantly lower than the reference site (Table 18b).

Quality Control (QC)

The variability in test results discussed in the following sections includes not only the differences in responses due to sample and organism characteristics, but the variance due to laboratory practices and random error as well. In this study, variance due to laboratory practices and random error were assumed to be constant based on the randomization of all treatments and organisms in the bioassays. Quality control for the bioassays performed on the sediments collected in April, 2000 is described in Appendix A.

QC: Duplicate sediment bioassays

The results of the duplicate bioassays (Sheepshead Minnows: April, 2000 and for amphipods: October, 1999 and April, 2000 See Table 22) were averaged and these values were used in the calculation of means and standard errors for survival data and growth data (for April, 2000 samples only). In general, the relative percent difference (RPD) for field duplicate sample survival appears to be within an expected level for the variability in the distribution of contaminant residues in the environment, but the amphipod growth data (final weight, Table 23) with 6 of 8 duplicates having RPD > 30% indicates the organism may be much more sensitive to within station contaminant residue variability than the Sheepshead Minnow growth metric. The duplicate sediment bioassays were performed using true field replicates (not splits of one

homogenized sediment sample) collected at the selected stations. The variability expressed as the difference in percent survival provides an indication of the variability of the sediment toxicity at each station.

QC: Control sediments

Ware River sediments were used as the control sediments for both sampling events. These bioassays were performed using replicates of one composite sediment sample collected from the control site (Ware River = WRC). Mean survival of the amphipods (October, 1999: mean = 98.0%, SE = 2.0%; April, 2000: mean = 91.0, SE = 1.9%, Tables 7 and 24, respectively) and for the fish larvae (April, 2000: mean = 97.0%, SE = 2.0%, Table 21) to the Ware River sediments met the data quality indicators of a successful test. Mean survival in the control sediment for the Sheepshead Minnow and the amphipod was poor relative to the mean survival for the strata treatments (Table 25). The larval fish gained less weight in the control sediment than in any treatment including the reference sediment. The amphipod grew less in than one of the treatments, grew more in the reference sediment, but overall grew very little. In this study and with a 10-d exposure period to the Ware River control sediments, growth provided no additional information. The variability expressed as the mean and standard error for the number of surviving individuals is an indication of the variability of the response of the batch of test organisms to one sediment grab sample that was thoroughly homogenized and split into 5 aliquots. The initial number of test species was 20 individuals in all test chambers.

QC: Reference sediments

Carter Creek sediments were used as the reference sediments for this study. The results show that the reference site had lower survival and more variability than the reference site (Figures 1 and 2). Mean survival of the amphipods exposed to the reference sediments (Table 26) was 94.0% (October, 1999) and 85.5% (April, 2000). The observations of surviving amphipods in sediment bioassays were based on their response to 10 true field replicates collected in Carters Creek. Since these sediments were collected within a 100m x 100m grid at randomly located positions, the variability expressed as the mean and standard error for the number of amphipods surviving at the end of the study is an indication of the variability of the sediment toxicity (or quality of the sediment as a reference sample) at the reference site. The amphipod bioassays performed on both sample sets from the reference site had one test chamber with unusually low survival. This affected the mean survival and standard error for the both tests, but there is no justifiable reason to discard either result as an outlier since the site replicate was not the same in both tests.

QC: Reference Toxicants

The reference toxicant bioassays with both organisms for the October, 1999 bioassays did not meet the data quality indicators (DQI) required for a successful test. The exposure of Sheepshead Minnow eggs (age = 24 hours post fertilization) to cadmium chloride in the

traditional concentration dilution series had a mean control survival (n=5) of 80% with one replicate having a control survival of 60%. Although the control survival data can be used with routine statistical correction procedures for control mortalities (e.g., Abbott's correction), the response of the eggs to the dilution series was atypical and not amenable to the calculation of a valid LC50 for comparison to reference toxicant control charts. The most obvious explanation for the unexpected responses is the presence of ammonia at high concentrations (20 mg/L) in the culture water used to prepare the dilution series. This test would have been invalid even if the control survival data met the requirements of the statistical methods used to derive an LC50.

The mean control survival (n=2) for the amphipod in the October, 1999 reference toxicant bioassay was 30%, well below the DQI of 90%. This extreme rate of mortality in the controls cannot be corrected and a valid LC50 cannot be determined with these data. The results of the reference toxicant test does not meet the DQIs for this study.

The reference toxicant results for the April, 2000 bioassays are described in Appendix B. The results for the amphipod and minnow reference toxicant bioassays met the contract laboratory's historical performance expectation for acceptable tests.

Ancillary Data

Pore (interstitial) water was extracted from aliquots of each sediment sample used in the bioassays and analyzed for nitrite, ammonia and sulfides (Table 27). These data represent the conditions of the sediment after collection and storage, but do not represent the conditions at the beginning of the sediment bioassay. Interstitial ammonia for sediments used in the bioassays with concentrations in the range of 5.0 to 13.0 mg/L (27% of the bioassays) showed no mortality greater than 25% of the test organisms. Nitrite in the range of 0.003 to 0.083 mg/L in sediment porewater yielded mortality not greater than 15% and sulfide in the range of 2.55 to 6.65 mg/L showed no mortality greater than 25%. There was no apparent correlation between increasing concentration of any of these parameters and increasing mortality.

Sediment organic carbon was similar throughout the study area as well as the reference and control sites. Total organic carbon ranged from 3 to 4.4 % (Table 28) in all samples and there was no apparent relationship between toxicity and sediment organic carbon content.

Particle Size Characteristics

The results of analysis for sediment particle size characteristics are provided in Table 29 for sediment collected in October, 1999 and in Table 30 for the April, 2000 sediment collection event. The results in Table 30 vary slightly from the results presented in Appendix C due to adjustments for percent gravel. That is, sediment bioassays and sediment contaminant analysis do not normally use particles greater than 2 mm in size (e.g., operational definition for gravel), thus it is important to report comparable data for all components of the study. Although all practical means were used to collect sediment at the same locations, there are limitations to the

positioning equipment and if there was any heterogeneity in the sediment characteristics, it would be revealed in the comparison of fines, or the sum of the percent silt and clay (Table 31), from both sediment collections.

The comparison of sediment particle size characteristics between sediments collected in October, 1999 and April, 2000 based on the percent fines (Table 31), where fines are defined as the sum of the % sand and % clay, shows less than 5 of the samples are different between the two collection events. The relative percent difference (RPD), the absolute difference between the values divided by the mean, provides a rough estimate of the similarity of the samples collected at approximately the same location during the two sampling periods. For an RPD greater than 40%, it must be assumed that: 1) the same exact station was not sampled; 2) the sediment was disturbed or altered between the two sampling events; 3) sediment characteristics vary greatly over short distances about the station sampled; or 4) there was an error in the analytical process. It is impossible with these data to resolve the cause for the differences observed.

DISCUSSION

Comparison of amphipod survival: October 1999 vs April 2000 sediment

The only comparison that can be made between the bioassays performed on the sediments collected in October 1999 and April 2000 is between amphipod survival. Growth measurements were not made for the October 1999 amphipod bioassays, but were included in the re-analysis based on review comments of earlier drafts of this report. Also, the Sheepshead Minnow bioassay for the October 1999 sediment failed, making any comparison to the re-analysis data impossible. Since the amphipod reference toxicant bioassay (positive control) for the October 1999 sediments failed to produce meaningful results, the sensitivity and health of the amphipods for the first round of amphipod bioassays could not be assessed relative to a long-term database. Differences in amphipod survival between the sediment collected from the two sampling periods (the same locations were sampled within the precision and accuracy of the differential beacon global positioning system) could be attributed to: 1) differences in sensitivity and health of the bioassay organism; 2) differences in the laboratory technique (in-house bioassays performed on October 1999 samples and contract lab bioassays performed on April 2000 samples); 3) differences in within-site contaminant distribution heterogeneity (DGPS accuracy providing approximately 5 m resolution about the true location); and 3) seasonal changes in sediment characteristics potentially affecting contaminant bioavailability and quality/quantity of particulate matter as food for the test organisms. These and other potential causes for the differences can be listed, although the data cannot resolve what caused any observed differences.

The mean survival for the control sediments (WRC) was less in the April, 2000 bioassays than the October, 1999 bioassays, but still above 90% suggesting that both tests were acceptable. The differences between the mean survival in the two tests was not significant ($p<0.05$), suggesting that one or more of the four differences (noted above) between the two bioassays may be responsible. It is interesting to note that the variability of each test is small (SE = 2.0% for

October 1999, SE = 1.9% for April 2000). A more dramatic difference is seen in the response of the test organisms to the reference sediment from Carters Creek. The reference sediment from Carters Creek was 10 randomly located grab samples using the same geographical position for both sampling events. The mean survival was 94.0% (SE = 3.5%) for the October 1999 sediment and 85.5 % (SE = 4.4%) for the April 2000 sediment. However, in both cases there was one sediment sample that had very low survival that could be called an outlier. If the potential outlier was removed from each study, the resulting mean survival would be 97.2% (SE = 1.5%) and 89.4 % (SE = 2.2%), respectively. For the October 1999 sediment bioassays, some strata would probably be significantly different from the reference site and there would be no difference between the reference and control sediment.

Comparison of amphipod survival: Leptocheirus vs Ampelisca bioassays

Direct comparison between the results of the two bioassays performed for this study using the amphipod *Leptocheirus plumulosus* and the study performed by USEPA (See Appendix D) using the amphipod *Ampelisca abdita* was not possible for several reasons. The differences between the studies include: 1) the USEPA study used sediment from a one foot depth integrated sample and this study used only the upper 2cm layer of surficial sediment; and 2) this study employed a random stratified sampling design and the USEPA study design may have targeted hot spots. Other differences may be revealed upon comparison of the methods applied by the two studies (e.g., volume of sediment and overlying water used in the bioassays, loading of organisms in test chambers).

Survival and growth of Sheepshead Minnows

Survival of the larval minnows exposed to the sediments showed very little acute toxicity at any strata sampled in this study. There was no statistically significant difference in survival between sediments from the various strata and the reference site. There was a significant difference in mean weights between the strata and the reference sediments, but mean *Cyprinodon variegatus* weights for all test sites were not significantly lower than the mean weight for the reference site.

CONCLUSIONS

Ambient toxicity in surficial sediments collected from random positions within predefined strata at three locations in the Elizabeth River was lower than originally expected. The results of the amphipod bioassays performed on surficial sediments collected in October, 1999 show that ambient toxicity in the three study areas appears to be low and may not be ecologically significant, but the results of the reference toxicant bioassay does not allow for an assessment of the sensitivity and health of the test organisms. The Sheepshead Minnow embryo-larval bioassay performed with these sediments was compromised by a fungal infestation and the results do not provide any meaningful data. The results of a re-sampling event in April, 2000 of

the same strata using the same locations within each strata showed that no strata were impaired based on amphipod survival, amphipod growth, fish larvae survival or fish larvae growth.

A concern expressed during the review of an earlier draft of this report was that the results of the bioassays for the Scuffletown Creek strata using the amphipod *Leptocheirus plumulosus* (October, 1999 sampling event) does not agree with earlier work performed by USEPA using the amphipod *Ampelisca abdita*. The differences in the results of the toxicity tests may be due to several factors. The studies were performed at different times of the year and there may be seasonal influences on the bioavailability of the contaminants. One species may be more sensitive to the suite of toxicants present at the site than the other. The sampling approach for the sediments used for the *Ampelisca* bioassays may have targeted "hot spots," while the *Leptocheirus* were exposed to samples collected at randomly selected stations within each stratum in Scuffletown Creek. The sediments used for the *Ampelisca* bioassays were depth integrated from 0 to 1 foot depth samples, while the *Leptocheirus* were exposed to sediments from the surficial layer (0 to 2 cm). A direct comparison between the methods and the results from these two approaches may not be reasonable, but both results appear to real. The data may be suggesting that toxicity in the surficial layer is minimal, while at depth the contaminants are bioavailable or in sufficient concentrations to be toxic. This may be a situation where apparently conflicting data reveal more information that either data set alone. That is, if the results of the assessment of the benthic community health (B-IBI) being performed shows that deep dwelling organisms are absent or less abundant and less diverse than expected, yet the shallow dwelling organisms are present with abundance and diversity similar to reference conditions, this speculation would be supported.

These data are provided to VA DEQ-TRO in hard copy and electronic format (ascii delimited and Microsoft Excel spreadsheets) for additional analysis by the USACE Elizabeth River Sediment Steering Committee and others.

Comments provided by reviewers of an earlier draft of this report are included for reference (See Appendices E, F, and G).

Table 1. Sampling locations in Scuffletown Creek (SCFLT), reference (CCR) and control (WRC) sites for sediment collected in October, 1999. All positions were observed using DGPS (NAD83).

STRATA	REP	LAT	LON	WATERBODY	NOTE
SCFLT1	1	36.80932	-076.28205	Scuffletown Creek	Northeast
SCFLT1	2	36.80918	-076.28082	Scuffletown Creek	Northeast
SCFLT1	3	36.80920	-076.27987	Scuffletown Creek	Northeast
SCFLT1	3D	36.80920	-076.27987	Scuffletown Creek	Northeast
SCFLT1	4	36.80925	-076.27893	Scuffletown Creek	Northeast
SCFLT1	5	36.80893	-076.28107	Scuffletown Creek	Northeast
SCFLT2	1	36.80868	-076.28567	Scuffletown Creek	Midregion
SCFLT2	2	36.80910	-076.28347	Scuffletown Creek	Midregion
SCFLT2	3	36.80838	-076.28397	Scuffletown Creek	Midregion
SCFLT2	3D	36.80838	-076.28397	Scuffletown Creek	Midregion
SCFLT2	4	36.80862	-076.28347	Scuffletown Creek	Midregion
SCFLT2	5	36.80807	-076.28368	Scuffletown Creek	Midregion
SCFLT3	1	36.80862	-076.28715	Scuffletown Creek	Northwest
SCFLT3	2	36.80800	-076.28803	Scuffletown Creek	Northwest
SCFLT3	2D	36.80800	-076.28803	Scuffletown Creek	Northwest
SCFLT3	3	36.80828	-076.28785	Scuffletown Creek	Northwest
SCFLT3	4	36.80803	-076.28702	Scuffletown Creek	Northwest
SCFLT3	5	36.80860	-076.28722	Scuffletown Creek	Northwest
SCFLT4	1	36.80712	-076.28668	Scuffletown Creek	Southwest
SCFLT4	2	36.80780	-076.28762	Scuffletown Creek	Southwest
SCFLT4	3	36.80672	-076.28898	Scuffletown Creek	Southwest
SCFLT4	4	36.80698	-076.28818	Scuffletown Creek	Southwest
SCFLT4	4D	36.80698	-076.28818	Scuffletown Creek	Southwest
SCFLT4	5	36.80710	-076.28747	Scuffletown Creek	Southwest
CCR	1	37.32758	-076.57170	Carters Creek	Reference
CCR	2	37.32778	-076.57183	Carters Creek	Reference
CCR	3	37.32737	-076.57165	Carters Creek	Reference
CCR	4	37.32705	-076.57153	Carters Creek	Reference
CCR	5	37.32717	-076.57167	Carters Creek	Reference
CCR	6	37.32688	-076.57187	Carters Creek	Reference
CCR	7	37.32778	-076.57197	Carters Creek	Reference
CCR	8	37.32747	-076.57135	Carters Creek	Reference
CCR	9	37.32713	-076.57213	Carters Creek	Reference
CCR	10	37.32772	-076.57228	Carters Creek	Reference
WRC	1-5	37.40820	-076.48932	Ware River	Control

Table 2. Sampling locations in Scotts Creek (SCTTS), Campostella (CPSTL), reference (CCR), and control (WRC) sites for sediment collected in October, 1999. All positions were observed using DGPS (NAD83).

STRATA	REP	LAT	LON	WATERBODY	NOTE
SCTTS1	1	36.84602	-076.32618	Scotts Creek	
SCTTS1	1D	36.84602	-076.32618	Scotts Creek	
SCTTS1	2	36.84678	-076.32443	Scotts Creek	
SCTTS1	3	36.84187	-076.32178	Scotts Creek	
SCTTS1	4	36.84367	-076.32197	Scotts Creek	
SCTTS1	5	36.84620	-076.31865	Scotts Creek	
SCTTS1	6	36.84595	-076.31892	Scotts Creek	
SCTTS1	6D	36.84595	-076.31892	Scotts Creek	
SCTTS1	7	36.84752	-076.31898	Scotts Creek	
SCTTS1	8	36.84660	-076.31695	Scotts Creek	
SCTTS1	9	36.84467	-076.31603	Scotts Creek	
SCTTS1	10	36.84545	-076.31602	Scotts Creek	
CPSTL1	1	36.83842	-076.25933	Campostella Bridge	
CPSTL1	2	36.83810	-076.26138	Campostella Bridge	
CPSTL1	3	36.83845	-076.26222	Campostella Bridge	
CPSTL1	4	36.83835	-076.26197	Campostella Bridge	
CPSTL1	5	36.83907	-076.26620	Campostella Bridge	
CPSTL1	5D	36.83907	-076.26620	Campostella Bridge	
CPSTL1	6	36.83802	-076.25955	Campostella Bridge	
CPSTL1	6D	36.83802	-076.25955	Campostella Bridge	
CPSTL1	7	36.83880	-076.26620	Campostella Bridge	
CPSTL1	8	36.83788	-076.25917	Campostella Bridge	
CPSTL1	9	36.83790	-076.25605	Campostella Bridge	
CPSTL1	10	36.83740	-076.25658	Campostella Bridge	
CCR	1	37.32758	-076.57170	Carters Creek	Reference
CCR	2	37.32778	-076.57183	Carters Creek	Reference
CCR	3	37.32737	-076.57165	Carters Creek	Reference
CCR	4	37.32705	-076.57153	Carters Creek	Reference
CCR	5	37.32717	-076.57167	Carters Creek	Reference
CCR	6	37.32688	-076.57187	Carters Creek	Reference
CCR	7	37.32778	-076.57197	Carters Creek	Reference
CCR	8	37.32747	-076.57135	Carters Creek	Reference
CCR	9	37.32713	-076.57213	Carters Creek	Reference
CCR	10	37.32772	-076.57228	Carters Creek	Reference
WRC	1-5	37.40820	-076.48932	Ware River	Control

Table 3. Sampling locations in Scuffletown Creek (SCFLT), reference (CCR) and control (WRC) sites for sediment collected in April, 2000. All positions were observed using DGPS (NAD83).

STRATA	REP	LAT	LON	WATERBODY	NOTE
SCFLT1	1	36.80915	-076.27983	Scuffletown Creek	Northeast
SCFLT1	2	36.80888	-076.28012	Scuffletown Creek	Northeast
SCFLT1	3	36.80910	-076.28047	Scuffletown Creek	Northeast
SCFLT1	3D	36.80910	-076.28047	Scuffletown Creek	Northeast
SCFLT1	4	36.80897	-076.28145	Scuffletown Creek	Northeast
SCFLT1	5	36.80892	-076.28120	Scuffletown Creek	Northeast
SCFLT2	1	36.80868	-076.28567	Scuffletown Creek	Midregion
SCFLT2	2	36.80910	-076.28347	Scuffletown Creek	Midregion
SCFLT2	3	36.80838	-076.28393	Scuffletown Creek	Midregion
SCFLT2	3D	36.80838	-076.28393	Scuffletown Creek	Midregion
SCFLT2	4	36.80857	-076.28342	Scuffletown Creek	Midregion
SCFLT2	5	36.80855	-076.28330	Scuffletown Creek	Midregion
SCFLT3	1	36.80862	-076.28715	Scuffletown Creek	Northwest
SCFLT3	2	36.80803	-076.28797	Scuffletown Creek	Northwest
SCFLT3	2D	36.80803	-076.28797	Scuffletown Creek	Northwest
SCFLT3	3	36.80833	-076.28783	Scuffletown Creek	Northwest
SCFLT3	4	36.80800	-076.28707	Scuffletown Creek	Northwest
SCFLT3	5	36.80863	-076.28718	Scuffletown Creek	Northwest
SCFLT4	1	36.80627	-076.28718	Scuffletown Creek	Southwest
SCFLT4	2	36.80750	-076.29238	Scuffletown Creek	Southwest
SCFLT4	3	36.80668	-076.28892	Scuffletown Creek	Southwest
SCFLT4	4	36.80698	-076.28815	Scuffletown Creek	Southwest
SCFLT4	4D	36.80698	-076.28815	Scuffletown Creek	Southwest
SCFLT4	5	36.80707	-076.28750	Scuffletown Creek	Southwest
CCR	1	37.32770	-076.57250	Carters Creek	Reference
CCR	2	37.32755	-076.57165	Carters Creek	Reference
CCR	3	37.32788	-076.57183	Carters Creek	Reference
CCR	4	37.32727	-076.57227	Carters Creek	Reference
CCR	5	37.32733	-076.57175	Carters Creek	Reference
CCR	6	37.32697	-076.57198	Carters Creek	Reference
CCR	7	37.32752	-076.57223	Carters Creek	Reference
CCR	8	37.32718	-076.57165	Carters Creek	Reference
CCR	9	37.32713	-076.57220	Carters Creek	Reference
CCR	10	37.32783	-076.57183	Carters Creek	Reference
WRC	1-5	37.40817	-076.48942	Ware River	Control

Table 4. Sampling locations in Scotts Creek (SCTTS), Campostella (CPSTL), reference (CCR), and control (WRC) sites for sediment collected in April, 2000. All positions were observed using DGPS (NAD83).

STRATA	REP	LAT	LON	WATERBODY	NOTE
SCTTS1	1	36.84623	-076.32603	Scotts Creek	
SCTTS1	1D	36.84623	-076.32603	Scotts Creek	
SCTTS1	2	36.84673	-076.32450	Scotts Creek	
SCTTS1	3	36.84177	-076.32183	Scotts Creek	
SCTTS1	4	36.84362	-076.32198	Scotts Creek	
SCTTS1	5	36.84623	-076.31868	Scotts Creek	
SCTTS1	6	36.84585	-076.31898	Scotts Creek	
SCTTS1	6D	36.84585	-076.31898	Scotts Creek	
SCTTS1	7	36.84747	-076.31893	Scotts Creek	
SCTTS1	8	36.84667	-076.31695	Scotts Creek	
SCTTS1	9	36.84493	-076.31595	Scotts Creek	
SCTTS1	10	36.84550	-076.31592	Scotts Creek	
CPSTL1	1	36.83848	-076.25932	Campostella Bridge	
CPSTL1	2	36.83815	-076.26130	Campostella Bridge	
CPSTL1	3	36.83850	-076.26220	Campostella Bridge	
CPSTL1	4	36.83838	-076.26207	Campostella Bridge	
CPSTL1	5	36.83915	-076.26623	Campostella Bridge	
CPSTL1	5D	36.83915	-076.26623	Campostella Bridge	
CPSTL1	6	36.83802	-076.25950	Campostella Bridge	
CPSTL1	6D	36.83802	-076.25950	Campostella Bridge	
CPSTL1	7	36.83865	-076.26608	Campostella Bridge	
CPSTL1	8	36.83793	-076.25908	Campostella Bridge	
CPSTL1	9	36.83788	-076.25600	Campostella Bridge	
CPSTL1	10	36.83740	-076.25650	Campostella Bridge	
CCR	1	37.32770	-076.57250	Carters Creek	Reference
CCR	2	37.32755	-076.57165	Carters Creek	Reference
CCR	3	37.32788	-076.57183	Carters Creek	Reference
CCR	4	37.32727	-076.57227	Carters Creek	Reference
CCR	5	37.32733	-076.57175	Carters Creek	Reference
CCR	6	37.32697	-076.57198	Carters Creek	Reference
CCR	7	37.32752	-076.57223	Carters Creek	Reference
CCR	8	37.32718	-076.57165	Carters Creek	Reference
CCR	9	37.32713	-076.57220	Carters Creek	Reference
CCR	10	37.32783	-076.57183	Carters Creek	Reference
WRC	1-5	37.40817	-076.48942	Ware River	Control

Table 5. Survival of the Sheepshead Minnow fry (10 organisms per test container) after exposure for 10 days to sediments collected in October, 1999. The number of bioassays are indicated under the column heading "N", followed by the mean and standard error (SE). Note that the replicate values for the control sediments (WRC) are replicates measuring bioassay organism response variability to splits of one homogeneous sediment grab sample, while the reference sediments (CCR) are individual samples from 10 random locations from within a 100m x 100m grid located in Carters Creek. Survival of test organisms in duplicate sediment samples was averaged.

10-day Sheepshead Minnow Sediment Bioassay
Number of Survivors at day-10
October, 1999

STRATA	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	N	MEAN	SE
SCFLT1	3.0	8.0	6.0	6.0	6.0						5	5.8	0.80
SCFLT2	5.0	6.0	6.0	5.0	8.0						5	6.0	0.55
SCFLT3	6.0	7.5	8.0	8.0	8.0						5	7.5	0.39
SCFLT4	7.0	6.0	4.0	4.5	6.0						5	5.5	0.55
SCTTS1	6.5	5.0	4.0	5.0	5.0	7.0	8.0	7.0	7.0	7.0	10	6.2	0.41
CPSTL1	7.0	9.0	7.0	6.0	6.0	7.0	7.0	7.0	9.0	9.0	10	7.4	0.37
CCR	7.0	5.0	8.0	6.0	5.0	4.0	7.0	8.0	9.0	7.0	10	6.6	0.50
WRC	6.0	7.0	6.0	3.0	7.0						5	5.8	0.73

STRATA
SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 6. Reference Toxicant Bioassay Data for Cyprinodon variegatus (Sheepshead Minnow) for the October, 1999 sediment study. Results did not provide a valid LC50.

Test Conditions:

Temperature:	20^0C ±1^0C.
Dissolved Oxygen:	Initial = 7.5 mg/L, range 6.7 to 7.8, no aeration.
pH:	Initial = 8.3 su, range 8.1 to 8.3, no adjustments.
Salinity:	Initial = 20 psu, fresh culture water.
Ammonia:	Initial = 20 mg/L (by LaMotte test kit).
Test Chamber:	200 mL solution in 250 mL bowls.
Culture water:	Instant Ocean Sea Salts dissolved in de-ionized water.
Test Duration/type:	96 hour, static acute, non-renewal bioassay.
Reference toxicant:	Cadmium chloride (anhydrous).
Embryos:	Less than 24hrs post fertilization.
Exposure:	100 % $CdCl_2$ = 4.2776 mg $CdCl_2$/L 20 psu culture water.
Treatment:	10 organisms per replicate, 2 replicates per treatment (or dilution).
Test Period:	2-6 November, 1999.
Test Matrix:	Sediments press sieved through a 500 µm sieve.

Results:

CONC	REPL	# OF LIVE ORGANISMS (EGGS + FISH)						%	MEAN %	CONC
$CdCl_2$	NUM	0 HR	1 HR	24 HR	48 HR	72 HR	96 HR	SURV	SURV	$CdCl_2$
100%	1	10	10	10	10	10	9	90%		
100%	2	10	10	10	10	8	6	60%	75.0%	100%
50%	1	10	10	10	10	9	8	80%		
50%	2	10	10	10	10	9	7	70%	75.0%	50%
25%	1	10	10	10	10	8	8	80%		
25%	2	10	10	10	10	10	8	80%	80.0%	25%
12.50%	1	10	10	10	10	8	8	80%		
12.50%	2	10	10	10	10	8	8	80%	80.0%	12.50%
6.25%	1	10	10	10	10	7	5	50%		
6.25%	2	10	10	10	10	7	6	60%	55.0%	6.25%
0%	1	10	10	10	10	10	8	80%		
0%	2	10	10	10	10	10	10	100%		
0%	3	10	10	10	10	7	8	80%		
0%	4	10	10	10	10	8	8	80%		
0%	5	10	10	10	10	7	6	60%	80.0%	0%

Table 7. Survival of the amphipod *Leptocheirus plumulosus* after 20 individuals were exposed for 10 days to sediments collected in October, 1999. The number of bioassays are indicated under the column heading "N", followed by the mean and standard error (SE). Note that the replicate values for the control sediments (WRC) are replicates measuring bioassay organism response variability to splits of one homogeneous sediment grab sample, while the reference sediments (CCR) are individual samples from 10 random locations from within a 100m x 100m grid located in Carters Creek. Survival of test organisms in duplicate sediment samples was averaged.

10-day Amphipod Sediment Bioassay
Percent Survival
October, 1999

STRATA	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	N	MEAN	SE
SCFLT1	95.0	95.0	85.0	70.0	85.0						5	86.0	4.6
SCFLT2	90.0	85.0	92.5	95.0	85.0						5	89.5	2.0
SCFLT3	90.0	85.0	90.0	85.0	85.0						5	87.0	1.2
SCFLT4	95.0	95.0	95.0	92.5	85.0						5	92.5	1.9
SCTTS1	87.5	90.0	90.0	100.0	100.0	92.5	95.0	70.0	85.0	80.0	10	89.0	2.9
CPSTL1	95.0	90.0	65.0	95.0	90.0	97.5	90.0	85.0	85.0	95.0	10	88.8	3.0
CCR	90.0	100.0	100.0	100.0	90.0	95.0	100.0	65.0	100.0	100.0	10	94.0	3.5
WRC	100.0	100.0	100.0	100.0	90.0						5	98.0	2.0

STRATA
SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 8. Reference Toxicant Bioassay Data for *Leptocheirus plumulosus* (estuarine amphipod) for the October, 1999 sediment study. The results do not provide a valid LC50.

Test Conditions:

Temperature:	$20^0C \pm 1^0C$ (range 19^0C to 21^0C).
Dissolved Oxygen:	Initial = 7.8 mg/L, range 6.8 to 7.8, no aeration.
pH:	Initial = 8.3 su, range 8.0 to 8.3, no adjustments.
Salinity:	Initial = 20 psu, fresh culture water.
Ammonia:	Initial = 0 mg/L (by LaMotte test kit).
Test Chamber:	200 mL solution in 250 mL bowls.
Culture water:	Instant Ocean Sea Salts dissolved in de-ionized water.
Test Duration/type:	96 hour, static acute, non-renewal bioassay.
Reference toxicant:	Cadmium chloride
Amphipods:	2-4 mm juveniles randomly selected from individuals passing through a 710 µm sieve and retained on a 425 µm sieve.
Exposure:	100 % $CdCl_2$ = 3.2082 mg $CdCl_2$/L 20 psu culture water.
Treatment:	10 organisms per replicate, 2 replicates per treatment (or dilution).
Test Period:	16-20 November, 1999.
Test Matrix:	Sediments press sieved through a 500 µm sieve.

Results:

CONC		# OF LIVE AMPHIPODS					%	MEAN %	CONC
$CdCl_2$	REP	0 HR	1 HR	24 HR	48 HR[1]	72 HR	96 HR	SURV	SURV	$CdCl_2$
100%	1	10	10	10	7	5	50%		
100%	2	10	10	10	9	5	50%	50.0%	100%
50%	1	10	10	10	8	8	80%		
50%	2	10	10	10	10	6	60%	70.0%	50%
25%	1	10	10	10	8	7	70%		
25%	2	10	10	10	8	7	70%	70.0%	25%
12.50%	1	10	10	10	9	9	90%		
12.50%	2	10	10	10	10	9	90%	90.0%	12.50%
6.25%	1	10	10	10	8	6	60%		
6.25%	2	10	10	10	9	9	90%	75.0%	6.25%
0%	1	10	10	10	2	1	10%		
0%	2	10	10	10	6	5	50%	30.0%	0%

Note 1: No count of survivors was performed at 48 hours of exposure.

Table 9. Tests for normality and homogeneity of variances for selection of parameters analyzed for hypothesis testing for lethal and sublethal effects. An "*" next to the variable name indicates that the variable was used to test for lethal or sublethal effects.

October, 1999 sediment bioassay					
	Shapiro-Wilk's		Bartlett's Test for		
Leptocheirus plumulosus	Test for Normality		Homogeneity of Variances		
	Shapiro-Wilk's				
Variable	W value	Prob. < W	χ^2 value	D.F.	P-value
Untransformed survival	0.8519	0.0001	13.4281	7	0 0623
Arc-sine transformed survival	0.8977	0.0001	8.8461	7	0.2639
Ranks of survival*	0.9635	0.1840	4 8312	7	0.6806
Normalized rankits of survival	0.9546	0.0712	7.6039	7	0.3688
April, 2000 sediment bioassays					
	Shapiro-Wilk's		Bartlett's Test for		
Leptocheirus plumulosus	Test for Normality		Homogeneity of Variances		
	Shapiro-Wilk's				
Variable	W value	Prob. < W	χ^2 value	D.F.	P-value
Untransformed survival	0.9385	0.0110	12.7426	7	0.0786
Arc-sine transformed survival*	0.9582	0.1060	4.9665	7	0.6641
Ranks of survival	0.9492	0.0387	3.2911	7	0.8568
Normalized rankits of survival	0.9707	0.3584	3.7391	7	0.8093
April, 2000 sediment bioassays					
	Shapiro-Wilk's		Bartlett's Test for		
Leptocheirus plumulosus	Test for Normality		Homogeneity of Variances		
	Shapiro-Wilk's				
Variable	W value	Prob. < W	χ^2 value	D.F.	P-value
Untransformed weight	0.9640	0.1927	16.8385	7	0.0185
Arc-sine transformed weight	0.9751	0.5093	14.3993	7	0.0445
Ranks of weight	0.9526	0.0573	12.5901	7	0.0827
Normalized rankits of weight*	0.9648	0.2076	11.9765	7	0.1013
April, 2000 sediment bioassays					
	Shapiro-Wilk's		Bartlett's Test for		
Cyprinodon variegatus	Test for Normality		Homogeneity of Variances		
	Shapiro-Wilk's				
Variable	W value	Prob. < W	χ^2 value	D.F.	P-value
Untransformed survival†	0.8016	0.0001	-17.0812	7	na
Arc-sine transformed survival	0.8909	0.0001	-7.2208	7	na
Ranks of survival	0.8367	0.0001	17.2854	7	0.0156
Normalized rankits of survival	0.8570	0.0001	-2.1878	7	na
April, 2000 sediment bioassays					
	Shapiro-Wilk's		Bartlett's Test for		
Cyprinodon variegatus	Test for Normality		Homogeneity of Variances		
	Shapiro-Wilk's				
Variable	W value	Prob. < W	χ^2 value	D.F.	P-value
Untransformed weight*	0.9555	0.0789	2.8845	7	0.8955
Arc-sine transformed weight	0.9420	0.0169	4.5684	7	0.7125
Ranks of weight	0.9688	0.3042	3.1707	7	0.8688
Normalized rankits of weight	0.9662	0.2377	1.3574	7	0.9868

Table 10. Descriptive statistics for ranks of *Leptocheirus plumulosus* survival for the October, 1999 sediment bioassay.

Station	N	Mean	Maximum	Minimum	Standard Error	Standard Deviation
CCR	10	38.150	49.500	1.500	5.351	16.920
CPSTL1	10	24.650	43.000	1.500	4.360	13.788
SCFLT1	5	19.900	37.000	3.500	7 114	15 908
SCFLT2	5	22.400	37.000	11.000	5 154	11 524
SCFLT3	5	15.800	23.000	11.000	2.939	6.573
SCFLT4	5	30.400	37.000	11.000	5.036	11.261
SCTTS1	10	24.850	49.500	3.500	5.270	16.665
WRC	5	44.200	49.500	23.000	5.300	11.851

Table 11. Descriptive statistics for arc-sine transformed *Leptocheirus plumulosus* survival for the April, 2000 sediment bioassays.

Station	N	Mean	Maximum	Minimum	Standard Error	Standard Deviation
CCR	10	1 187	1.345	0.785	0.052	0.166
CPSTL1	10	1.168	1.345	0.964	0.043	0.137
SCFLT1	5	1.225	1.345	1.107	0.040	0.090
SCFLT2	5	1.237	1.345	1.107	0.050	0.112
SCFLT3	5	1.106	1.249	0.938	0.062	0.138
SCFLT4	5	1.268	1.345	1.107	0.044	0.099
SCTTS1	10	1.152	1.345	1.047	0.033	0.105
WRC	5	1.272	1.345	1.173	0.033	0.073

Table 12. Descriptive statistics for normalized rankits of *Leptocheirus plumulosus* weights for the April, 2000 sediment bioassays.

Station	N	Mean	Maximum	Minimum	Standard Error	Standard Deviation
CCR	10	-0.688	-0.114	-1.669	0.179	0.566
CPSTL1	10	-0.356	0.575	-0.974	0.141	0.447
SCFLT1	5	1.439	2.280	0.774	0.258	0.576
SCFLT2	5	0.517	1.271	-0.869	0.364	0.815
SCFLT3	5	-0.161	1.175	-1.509	0.550	1.230
SCFLT4	5	-0.151	0.522	-2.085	0.487	1.088
SCTTS1	10	0.272	1.890	-2.085	0.367	1.159
WRC	5	-0.100	1.011	-0.744	0.300	0.671

Table 13. Descriptive statistics for *Cyprinodon variegatus* survival for the April, 2000 sediment bioassays.

Station	N	Mean	Maximum	Minimum	Standard Error	Standard Deviation
CCR	10	0.970	1.000	0.850	0.015	0.048
CPSTL1	10	0.990	1.000	0.950	0 007	0.021
SCFLT1	5	1.000	1.000	1 000	0.000	0 000
SCFLT2	5	0.965	1.000	0.875	0.024	0.055
SCFLT3	5	0.990	1.000	0.950	0.010	0.022
SCFLT4	5	0.955	1.000	0.850	0.028	0.062
SCTTS1	10	0.975	1.000	0.850	0.015	0.049
WRC	5	0.970	1.000	0.900	0.020	0.045

Table 14. Descriptive statistics for *Cyprinodon variegatus* weights for the April, 2000 sediment bioassays.

Station	N	Mean	Maximum	Minimum	Standard Error	Standard Deviation
CCR	10	0.734	0.897	0.596	0.028	0.088
CPSTL1	10	0.650	0.803	0.569	0.024	0.076
SCFLT1	5	0.718	0.899	0.644	0.047	0.105
SCFLT2	5	0.764	0.882	0.639	0.042	0.094
SCFLT3	5	0.638	0.726	0.576	0.026	0.057
SCFLT4	5	0.710	0.806	0.632	0.035	0.079
SCTTS1	10	0.798	0.922	0.688	0.023	0.073
WRC	5	0.623	0.684	0.568	0.023	0.052

Table 15. Pairwise comparisons of reference to control sediments for all variables.

Ranks of *L. plumulosus* survival - October, 1999 sediment bioassays

Site	N	Mean	Standard Deviation	Standard Error	T-value	D.F.	Prob>|T|
SITE	N	Mean	StdDev	StdError	T	DF	Prob>|T|
CCR	10	38.150	16.920	5.351	-0.7109	13	0 4897
WRC	5	44.200	11.851	5.300			

Arc-sine transformed *L. plumulosus* survival - April, 2000 sediment bioassays.

Site	N	Mean	Standard Deviation	Standard Error	T-value	D.F.	Prob>|T|
SITE	N	Mean	StdDev	StdError	Tvalue	DF	Prob>|T|
CCR	10	1.187	0.166	0.052	-1.0835	13	0.2983
WRC	5	1.272	0.073	0.033			

Normalized rankits of *L. plumulosus* weight - April, 2000 sediment bioassays.

Site	N	Mean	Standard Deviation	Standard Error	T-value	D.F.	Prob>|T|
SITE	N	Mean	StdDev	StdError	T	DF	Prob>|T|
CCR	10	-0.688	0.566	0.179	-1.7898	13	0.0968
WRC	5	-0.100	0.671	0.300			

C. variegatus survival - April, 2000 sediment bioassays.

Site	N	Mean	Standard Deviation	Standard Error	T-value	D.F.	Prob>|T|
SITE	N	Mean	StdDev	StdError	T	DF	Prob>|T|
CCR	10	0.970	0.048	0.015	0.0000	13.0	1 0000
WRC	5	0.970	0.045	0.020			

C. variegatus weight - April, 2000 sediment bioassays.

Site	N	Mean	Standard Deviation	Standard Error	T-value	D.F.	Prob>|T|
SITE	N	Mean	StdDev	StdError	T	DF	Prob>|T|
CCR	10	0.734	0.088	0.028	2.5641	13.0	0.024
WRC	5	0.623	0.052	0.023			

Table 16. Results of the a) one-way ANOVA and b) Bonferroni T-tests for ranks of *Leptocheirus plumulusos* survival for the October, 1999 sediment bioassays.

a) one-way ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-Value	Prob>F	R-Square
Model	6	2368.31	394.72	1.88	0.1056	0.208
Error	43	9010.48	209.55			
Corrected Total	49	11378.78				

b) Bonferroni T-tests

Site	N	Mean	Bonferroni Grouping
CCR	10	38.150	1
SCFLT4	5	30.400	1
SCTTS1	10	24.850	1
CPSTL1	10	24.650	1
SCFLT2	5	22.400	1
SCFLT1	5	19.900	1
SCFLT3	5	15.800	1

Table 17. Results of the a) one-way ANOVA and b) Fisher's LSD range test for arc-sine transformed *Leptocheirus plumulusos* survival, April, 2000 sediment bioassays.

a) one-way ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-Value	Prob>F	R-Square
Model	6	0.101	0.017	1.02	0.4267	0.124
Error	43	0.712	0.017			
Corrected Total	49	0.813				

b) Bonferroni T-tests

Site	N	Mean	Bonferroni Grouping
SCFLT4	5	41.600	1
SCFLT2	5	37.700	1
SCFLT1	5	35.800	1
CCR	10	28.300	1
CPSTL1	10	22.200	1
SCTTS1	10	21.250	1
SCFLT3	5	15.400	1

Table 19. Results of the a) Kruskal-Wallis test and b) Wilcoxon Rank Sum tests for *Cyprinodon variegatus* survival, April, 2000 sediment bioassays.

a) Kruskal-Wallis test

Site	N	Sum of Scores	Expected Under H_0	Standard Deviation H_0	Mean Score	Chi-square value	D.F.	Prob > Chi-square
CCR	10	228.50	255.00	33.22	22.85	5.5103	6	0.4802
CPSTL1	10	283.00	255.00	33.22	28.30			
SCFLT1	5	165.00	127.50	24.91	33.00			
SCFLT2	5	112.50	127.50	24.91	22.50			
SCFLT3	5	141.50	127.50	24.91	28.30			
SCFLT4	5	92.50	127.50	24.91	18.50			
SCTTS1	10	252.00	255.00	33.22	25.20			

b) Wilcoxon Rank Sum tests

Site	N	Sum of Scores	Expected Under H_0	Standard Deviation H_0	Mean Score	S value	Z-value	Prob > Z
CCR	10	70.0	80.0	6.32	7.0	50.000	1.5021	0.1331
SCFLT1	5	50.0	40.0	6.32	10.0			
CCR	10	80.5	80.0	7.15	8.1	39.500	0.0000	1.0000
SCFLT2	5	39.5	40.0	7.15	7.9			
CCR	10	74.5	80.0	6.77	7.5	45.500	0.7385	0.4602
SCFLT3	5	45.5	40.0	6.77	9.1			
CCR	10	84.0	80.0	7.44	8.4	36.000	-0.4704	0.6381
SCFLT4	5	36.0	40.0	7.44	7.2			
CCR	10	100.5	105.0	11.15	10.1	100.500	-0.3587	0.7198
SCTTS1	10	109.5	105.0	11.15	11.0			
CCR	10	94.0	105.0	10.61	9.4	94.0000	-0.9899	0.3222
CPSTL1	10	116.0	105.0	10.61	11.6			

Table 20. Results of the a) one-way ANOVA and b) the Bonferroni T-tests for *Cyprinodon variegatus* weights, April, 2000 sediment bioassays.

a) one-way ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-Value	Prob>F	R-Square
Model	7	0.198	0.028	4 46	0.0007	0.399
Error	47	0 298	0 006			
Corrected Total	54	0.496				

b) Bonferroni T-tests

Site	N	Mean	Bonferroni Grouping	
SCTTS1	10	0.798	1	
SCFLT2	5	0.764	1	2
CCR	10	0.734	1	2
SCFLT1	5	0.718	1	2
SCFLT4	5	0.710	1	2
CPSTL1	10	0.650	1	2
SCFLT3	5	0.638		2
WRC	5	0.623		2

Table 21. Mean percent survival of the Sheepshead Minnow fry (10 organisms per test container) after exposure for 10 days to sediments collected in April, 2000. The number of bioassays are indicated under the column heading "N", followed by the mean and standard error (SE). Note that the replicate values for the control sediments (WRC) are replicates measuring bioassay organism response variability to splits of one homogeneous sediment grab sample, while the reference sediments (CCR) are individual samples from 10 random locations from within a 100m x 100m grid located in Carters Creek. Survival of test organisms in duplicate sediment samples was averaged.

10-day Sheepshead Minnow Sediment Bioassay
Number of Survivors at day-10
April, 2000

STRATA	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	N	MEAN	SE
SCFLT1	100.0	100.0	100.0	100.0	100.0						5	100.0	0.0
SCFLT2	95.0	100.0	87.5	100.0	100.0						5	96.5	2.4
SCFLT3	100.0	100.0	100.0	100.0	95.0						5	99.0	1.0
SCFLT4	100.0	85.0	95.0	97.5	100.0						5	95.5	2.8
SCTTS1	100.0	100.0	95.0	95.0	100.0	100.0	100.0	100.0	100.0	85.0	10	97.5	1.5
CPSTL1	100.0	100.0	100.0	100.0	100.0	95.0	100.0	100.0	95.0	100.0	10	99.0	0.7
CCR	100.0	95.0	100.0	95.0	100.0	100.0	85.0	95.0	100.0	100.0	10	97.0	1.5
WRC	95.0	90.0	100.0	100.0	100.0						5	97.0	2.0

STRATA
SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 22. Survival of individuals (amphipods and Sheepshead Minnows) used in sediment bioassays of field duplicate (two unique sediment samples collected at the same geographical location, not splits of one grab) samples.

Amphipod Survival - October 1999

STRATA	REP	OBS1	OBS2	RPD
SCFLT1	3	15	19	23.5%
SCFLT2	3	19	18	5.4%
SCFLT3	2	17	17	0.0%
SCFLT4	4	19	18	5.4%
SCTTS1	1	19	16	17.1%
SCTTS1	6	19	18	5.4%
CPSTL1	5	18	18	0.0%
CPSTL1	6	20	19	5.1%

Amphipod Survival - April 2000

STRATA	REP	OBS1	OBS2	RPD
SCFLT1	3	20	16	22.2%
SCFLT2	3	14	19	30.3%
SCFLT3	2	11	15	30.8%
SCFLT4	4	20	17	16.2%
SCTTS1	1	18	18	0.0%
SCTTS1	6	17	18	5.7%
CPSTL1	5	18	19	5.4%
CPSTL1	6	15	12	22.2%

Sheepshead Minnow Survival - April 2000

STRATA	REP	OBS1	OBS2	RPD
SCFLT1	3	20	20	0.0%
SCFLT2	3	19	16	17.1%
SCFLT3	2	20	20	0.0%
SCFLT4	4	19	20	5.1%
SCTTS1	1	20	20	0.0%
SCTTS1	6	20	20	0.0%
CPSTL1	5	20	20	0.0%
CPSTL1	6	19	19	0.0%

Table 23. Mean final weight of amphipods and Sheepshead Minnows used in sediment bioassays of field duplicate (two unique sediment samples collected at the same geographical location, not splits of one grab) samples.

Amphipod Final Weight - April 2000

STRATA	REP	OBS1	OBS2	RPD
SCFLT1	3	0.180	0.266	38.6%
SCFLT2	3	0.184	0.145	23.7%
SCFLT3	2	0.073	0.115	44.7%
SCFLT4	4	0.120	0.045	90.9%
SCTTS1	1	0.194	0.306	44.8%
SCTTS1	6	0.108	0.189	54.5%
CPSTL1	5	0.129	0.115	11.5%
CPSTL1	6	0.144	0.102	34.1%

Sheepshead Minnow Final Weight - April 2000

STRATA	REP	OBS1	OBS2	RPD
SCFLT1	3	0.850	0.571	39.3%
SCFLT2	3	0.818	0.945	14.4%
SCFLT3	2	0.533	0.719	29.7%
SCFLT4	4	0.725	0.635	13.2%
SCTTS1	1	0.899	0.789	13.0%
SCTTS1	6	0.748	0.849	12.6%
CPSTL1	5	0.596	0.542	9.5%
CPSTL1	6	0.601	0.612	1.8%

Table 24. Survival of the amphipod *Leptocheirus plumulosus* after 20 individuals were exposed for 10 days to sediments collected in April, 2000. The number of bioassays are indicated under the column heading "N", followed by the mean and standard error (SE). Note that the replicate values for the control sediments (WRC) are replicates measuring bioassay organism response variability to splits of one homogeneous sediment grab sample, while the reference sediments (CCR) are individual samples from 10 random locations from within a 100m x 100m grid located in Carters Creek. Survival of test organisms in duplicate sediment samples was averaged.

10-day Amphipod Sediment Bioassay
Percent Survival
April, 2000

STRATA	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	N	MEAN	SE
SCFLT1	95.0	100.0	90.0	85.0	90.0						5	92.0	2.5
SCFLT2	90.0	95.0	82.5	100.0	95.0						5	92.5	3.0
SCFLT3	90.0	65.0	90.0	75.0	75.0						5	79.0	4.8
SCFLT4	90.0	95.0	95.0	92.5	100.0						5	94.5	1.7
SCTTS1	90.0	75.0	80.0	80.0	80.0	87.5	75.0	75.0	95.0	100.0	10	83.8	2.8
CPSTL1	80.0	90.0	80.0	70.0	92.5	67.5	85.0	95.0	95.0	80.0	10	83.5	3.1
CCR	85.0	85.0	95.0	80.0	85.0	100.0	85.0	95.0	95.0	50.0	10	85.5	4.4
WRC	95.0	90.0	85.0	90.0	95.0						5	91.0	1.9

STRATA
SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 25. Summary of mean growth in weight (mg dry weight) and standard error (SE) for 10 day Sheepshead Minnow and amphipod sediment bioassays performed on sediments collected in April 2000. Survival was greater than 90% for exposure to control sediment (WRC). All samples were stratified random samples from within the study area including CCR, however, the Ware River control (WRC) was one grab sample used to perform 5 replicate bioassays.

SHEEPSHEAD MINNOW (mg dry weight)			AMPHIPOD (mg dry weight)		
STRATA	MEAN	SE	MEAN	SE	STRATA
SCFLT1	0.718	0.0468	0.218	0.0178	SCFLT1
SCFLT2	0.764	0.0421	0.168	0.0166	SCFLT2
SCFLT3	0.638	0.0257	0.141	0.0213	SCFLT3
SCFLT4	0.710	0.0354	0.138	0.0139	SCFLT4
SCTTS1	0.798	0.0232	0.160	0.0155	SCTTS1
CPSTL1	0.650	0.0241	0.128	0.0048	CPSTL1
CCR	0.734	0.0278	0.117	0.0052	CCR
WRC	0.623	0.0234	0.138	0.0138	WRC

STRATA

SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 26. Summary of mean survival (MEAN) and standard error (SE) for 10 day amphipod sediment bioassays performed on sediments collected in October 1999 and April 2000. An asterisk (*) indicates stratum significantly different ($p < 0.05$) from the reference sediment (CCR). Survival greater than 90% for exposure to control sediment (WRC) is required to validate the test. Reference toxicant (positive controls) results for the October 1999 sediment bioassays were unusable for assessing amphipod health or sensitivity. All samples were stratified random samples from within the study area including CCR, however, the Ware River control was one grab sample used to perform 5 replicate bioassays.

		OCTOBER 1999		APRIL 2000		
STRATA	**N**	**MEAN**	**SE**	**MEAN**	**SE**	**STRATA**
SCFLT1	5	86.0%	4.6%	92.0%	2.5%	SCFLT1
SCFLT2	5	89.5%	2.0%	92.5%	3.0%	SCFLT2
SCFLT3	5	87.0%	1.2%	79.0%	4.8%	SCFLT3
SCFLT4	5	92.5%	1.9%	94.5%	1.7%	SCFLT4
SCTTS1	10	89.0%	2.9%	83.8%	2.8%	SCTTS1
CPSTL1	10	88.8%	3.0%	83.5%	3.1%	CPSTL1
CCR	10	94.0%	3.5%	85.5%	4.4%	CCR
WRC	5	98.0%	2.0%	91.0%	1.9%	WRC

STRATA

SCFLT1 = northeast strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT2 = mid reach strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT3 = northwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCFLT4 = southwest strata, Scuffletown Creek, Southern Branch, Elizabeth River
SCCTS1 = Scotts Creek off the Mainstem, Elizabeth River
CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River
CCR = Carters Creek reference site, York River
WRC = Ware River control sediment.

Table 27 (a Sediment pore water characteristics for the Scuffletown Creek strata, October, 1999. Nitrite (NO2), ammonia (NH3), and sulfide (SULFIDE) measured in pore water extracted from aliquots of sediment used in the bioassays. All concentrations are reported as mg/L.

STRATA	REP	NO2	NH3	SULFIDE
SCFLT1	1	0.0021	5.376	0.187
SCFLT1	2	0.0017	7.441	6.653
SCFLT1	3	0.0021	8.639	5.398
SCFLT1	3D	0.0019	9.480	5.880
SCFLT1	4	0.0027	4.427	0.081
SCFLT1	5	0.0022	6.037	0.161
SCFLT2	1	0.0011	8.175	3.540
SCFLT2	2	0.0021	13.009	5.889
SCFLT2	3	0.0031	6.133	0.072
SCFLT2	3D	0.0024	6.088	0.061
SCFLT2	4	0.0028	5.459	0.045
SCFLT2	5	0.0017	5.660	0.030
SCFLT3	1	0.0045	2.927	0.087
SCFLT3	2	0.0016	3.103	0.027
SCFLT3	2D	0.0016	3.115	0.032
SCFLT3	3	0.0022	2.358	0.069
SCFLT3	4	0.0017	2.510	0.066
SCFLT3	5	0.0030	1.331	0.074
SCFLT4	1	0.0057	1.259	0.117
SCFLT4	2	0.0015	1.759	0.033
SCFLT4	3	0.0010	1.975	0.010
SCFLT4	4	0.0019	1.660	0.049
SCFLT4	4D	0.0020	1.651	0.046
SCFLT4	5	0.0023	1.334	0.069
SCTTS1	1	0.0011	4.304	0.028
SCTTS1	1D	0.0011	4.340	0.038
SCTTS1	2	0.0011	3.280	0.023
SCTTS1	3	0.0010	3.945	1.763
SCTTS1	4	0.0012	5.430	2.554
SCTTS1	5	0.0010	3.690	0.025
SCTTS1	6	0.0017	2.660	0.022
SCTTS1	6D	0.0013	2.963	0.017
SCTTS1	7	0.0012	2.463	0.023
SCTTS1	8	0.0020	2.882	0.030
SCTTS1	9	0.0013	3.852	0.022
SCTTS1	10	0.0019	4.977	0.018

Table 27 (b Sediment pore water characteristics for the Scotts Creek and Campostella strata. October, 1999. Nitrite (NO2), ammonia (NH3), and sulfide (SULFIDE) measured in pore water extracted from aliquots of sediment used in the bioassays. All concentrations are reported as mg/L.

STRATA	REP	NO2	NH3	SULFIDE
CPSTL1	1	0.0083	6.959	0.018
CPSTL1	2	0.0008	1.873	0.030
CPSTL1	3	0.0009	1.720	0.025
CPSTL1	4	0.0011	3.373	0.028
CPSTL1	5	0.0010	8.034	0.027
CPSTL1	5D	0.0009	8.217	0.014
CPSTL1	6	0.0009	3.708	0.015
CPSTL1	6D	0.0011	3.513	0.015
CPSTL1	7	0.0015	7.753	0.007
CPSTL1	8	0.0011	5.004	0.010
CPSTL1	9	0.0011	2.409	0.020
CPSTL1	10	0.0012	2.091	0.041

Table 27 (c Sediment pore water characteristics for the reference (CCR = Carters Creek reference) and control (WRC = Ware River control) sites, October, 1999. Nitrite (NO2), ammonia (NH3), and sulfide (SULFIDE) measured in pore water extracted from aliquots of sediment used in the bioassays. All concentrations are reported as mg/L.

STRATA	REP	NO2	NH3	SULFIDE
CCR	1	0.0011	3.415	0.007
CCR	2	0.0011	3.253	0.009
CCR	3	0.0008	2.454	<.005
CCR	4	0.0007	2.367	0.005
CCR	5	0.0007	1.513	0.007
CCR	6	0.0005	1.364	0.009
CCR	7	0.0006	1.543	0.009
CCR	8	0.0005	1.534	<.005
CCR	9	0.0006	1.549	0.010
CCR	10	0.0007	1.705	0.010
WRC	1	0.0007	2.654	<.005

Table 28 a) Sediment organic carbon content for aliquots of sediment collected in October, 1999 at Scuffletown Creek and used in the sediment bioassays. Results are expressed as percent total organic carbon (TOC).

STRATA	REP	TOC
SCFLT1	1	3.88%
SCFLT1	2	3.77%
SCFLT1	3	3.27%
SCFLT1	3D	3.72%
SCFLT1	4	3.50%
SCFLT1	5	3.27%
SCFLT2	1	3.61%
SCFLT2	2	3.30%
SCFLT2	3	3.42%
SCFLT2	3D	3.25%
SCFLT2	4	4.02%
SCFLT2	5	3.80%
SCFLT3	1	3.10%
SCFLT3	2	3.73%
SCFLT3	2D	3.52%
SCFLT3	3	3.51%
SCFLT3	4	3.86%
SCFLT3	5	4.09%
SCFLT4	1	3.25%
SCFLT4	2	3.90%
SCFLT4	3	3.21%
SCFLT4	4	3.65%
SCFLT4	4D	3.60%
SCFLT4	5	3.52%

Table 28 b) Sediment organic carbon content for aliquots of sediment collected in October, 1999 at Scotts Creek and Campostella sites and used in the sediment bioassays. Results are expressed as percent total organic carbon (TOC).

STRATA	REP	TOC
SCTTS1	1	3.05%
SCTTS1	1D	3.14%
SCTTS1	2	4.05%
SCTTS1	3	3.36%
SCTTS1	4	3.70%
SCTTS1	5	3.05%
SCTTS1	6	3.29%
SCTTS1	6D	3.68%
SCTTS1	7	3.64%
SCTTS1	8	3.22%
SCTTS1	9	3.56%
SCTTS1	10	3.38%
CPSTL1	1	3.39%
CPSTL1	2	3.38%
CPSTL1	3	3.21%
CPSTL1	4	3.65%
CPSTL1	5	3.73%
CPSTL1	5D	3.39%
CPSTL1	6	3.50%
CPSTL1	6D	3.74%
CPSTL1	7	3.55%
CPSTL1	8	3.62%
CPSTL1	9	4.00%
CPSTL1	10	3.86%

Table 28 c) Sediment organic carbon content for aliquots of sediment collected in October, 1999 at reference (CCR = Carters Creek reference) and control (WRC = Ware River control) sites. These sediments were used to evaluate the results of sediment bioassays for all strata. Results are expressed as percent total organic carbon (TOC).

STRATA	REP	TOC
CCR	1	3.44%
CCR	2	3.69%
CCR	3	3.79%
CCR	4	3.65%
CCR	5	3.51%
CCR	6	3.65%
CCR	7	3.38%
CCR	8	3.84%
CCR	9	3.84%
CCR	10	3.88%
WRC	1	4.42%

Table 29. Sediment particle size characteristics - October, 1999.

SITE	REP	% SAND	% SILT	% CLAY
SCFLT1	1	14.7	47.6	37.7
SCFLT1	2	7.2	49.3	43.5
SCFLT1	3	5.9	38.1	56.0
SCFLT1	3D	47.6	21.8	30.6
SCFLT1	4	19.3	33.1	47.6
SCFLT1	5	13.6	48.8	37.6
SCFLT2	1	5.9	50.7	43.4
SCFLT2	2	9.9	47.4	42.7
SCFLT2	3	32.1	40.3	27.6
SCFLT2	3D	7.9	58.1	34.1
SCFLT2	4	44.8	31.8	23.4
SCFLT2	5	15.8	44.0	40.2
SCFLT3	1	67.2	23.3	9.5
SCFLT3	2	29.5	38.1	32.5
SCFLT3	2D	41.3	34.9	23.8
SCFLT3	3	34.1	37.9	28.0
SCFLT3	4	18.9	42.1	39.0
SCFLT3	5	57.8	29.4	12.8
SCFLT4	1	78.0	14.3	7.7
SCFLT4	2	38.4	24.3	37.3
SCFLT4	3	36.2	27.8	36.0
SCFLT4	4	50.4	28.9	20.7
SCFLT4	4D	63.3	21.3	15.4
SCFLT4	5	63.2	24.3	12.6
SCTTS1	1	7.7	71.8	20.6
SCTTS1	1D	17.1	22.6	60.3
SCTTS1	2	6.3	38.0	55.7
SCTTS1	3	11.8	32.3	55.9
SCTTS1	4	6.5	32.5	61.0
SCTTS1	5	5.6	40.7	53.6
SCTTS1	6	10.4	53.2	36.4
SCTTS1	6D	9.0	67.1	23.9
SCTTS1	7	22.1	41.5	36.5
SCTTS1	8	53.0	18.5	28.4
SCTTS1	9	11.9	27.6	60.5
SCTTS1	10	5.3	40.8	53.9

Table 29. Sediment particle size characteristics - October, 1999. (Continued)

SITE	REP	% SAND	% SILT	% CLAY
CPSTL1	1	28.4	40.1	31.5
CPSTL1	2	31.0	57.9	11.1
CPSTL1	3	45.7	44.5	9.8
CPSTL1	4	19.8	37.2	43.0
CPSTL1	5	18.7	56.5	24.8
CPSTL1	5D	15.0	27.0	58.1
CPSTL1	6	20.2	61.0	18.7
CPSTL1	6D	15.0	42.5	42.5
CPSTL1	7	22.5	64.7	12.8
CPSTL1	8	9.9	74.8	15.3
CPSTL1	9	45.2	41.1	13.6
CPSTL1	10	33.8	56.2	9.9
CCR	1	2.9	55.5	41.6
CCR	2	0.7	62.0	37.4
CCR	3	4.8	54.9	40.3
CCR	4	3.4	59.1	37.5
CCR	5	3.2	54.5	42.3
CCR	6	3.4	53.1	43.4
CCR	7	2.3	53.7	44.0
CCR	8	3.7	53.4	43.0
CCR	9	3.6	55.7	40.7
CCR	10	2.2	51.3	46.5
WRC		3.7	65.5	30.8

Table 30. Sediment particle size characteristics - April, 2000.

SITE	REP	% Sand	% Silt	% Clay
SCFLT1	1	14.7	47.0	38.3
SCFLT1	2	6.1	47.8	46.1
SCFLT1	3	11.1	45.4	43.5
SCFLT1	3D	12.9	44.2	42.9
SCFLT1	4	35.6	39.6	24.8
SCFLT1	5	11.0	48.8	40.2
SCFLT2	1	6.9	47.8	45.3
SCFLT2	2	10.7	50.4	38.9
SCFLT2	3	44.5	34.5	20.9
SCFLT2	3D	32.7	40.9	26.4
SCFLT2	4	31.5	42.3	26.3
SCFLT2	5	45.8	30.8	23.4
SCFLT3	1	65.8	23.1	11.1
SCFLT3	2	42.6	27.4	30.1
SCFLT3	2D	32.7	31.2	36.1
SCFLT3	3	50.9	23.9	25.2
SCFLT3	4	14.4	40.2	45.3
SCFLT3	5	51.5	34.4	14.1
SCFLT4	1	83.2	11.8	5.0
SCFLT4	2	85.3	9.3	5.4
SCFLT4	3	38.2	23.7	38.1
SCFLT4	4	54.8	23.8	21.4
SCFLT4	4D	55.1	24.3	20.6
SCFLT4	5	59.5	24.9	15.6
SCTTS1	1	12.0	48.0	40.0
SCTTS1	1D	13.7	42.5	43.7
SCTTS1	2	6.3	46.8	46.9
SCTTS1	3	16.0	41.2	42.8
SCTTS1	4	8.9	46.2	44.9
SCTTS1	5	54.9	26.7	18.4
SCTTS1	6	25.6	43.1	31.3
SCTTS1	6D	13.5	50.4	36.1
SCTTS1	7	32.6	36.1	31.3
SCTTS1	8	22.2	44.8	33.0
SCTTS1	9	6.4	42.3	51.3
SCTTS1	10	5.4	48.1	46.5

Table 30. Sediment particle size characteristics - April, 2000. (Continued)

SITE	REP	% Sand	% Silt	% Clay
CPSTL1	1	19.0	32.9	48.0
CPSTL1	2	17.7	39.1	43.2
CPSTL1	3	38.0	25.7	36.3
CPSTL1	4	23.4	33.6	43.0
CPSTL1	5	10.5	31.3	58.2
CPSTL1	5D	18.4	28.4	53.3
CPSTL1	6	8.1	38.7	53.2
CPSTL1	6D	6.6	38.2	55.2
CPSTL1	7	28.5	24.4	47.1
CPSTL1	8	14.9	40.0	45.1
CPSTL1	9	26.2	24.7	49.1
CPSTL1	10	15.9	42.8	41.3
CCR	1	2.6	45.6	51.8
CCR	2	6.2	42.8	51.0
CCR	3	3.4	44.6	52.0
CCR	4	13.4	43.4	43.2
CCR	5	7.3	46.1	46.6
CCR	6	3.5	46.1	50.4
CCR	7	4.9	40.9	54.2
CCR	8	7.1	44.2	48.7
CCR	9	10.0	43.9	46.1
CCR	10	6.5	46.3	47.2
WRC		8.7	38.1	53.2

Table 31. Comparison of sediment particle sizes

A comparison of sediment particle size characteristics between sediments collected in October, 1999 and April, 2000 based on the percent fines, where fines are defined as the sum of the % silt and % clay. The relative percent difference (RPD), the absolute difference between the values divided by the mean, provides an estimate of the similarity of the samples collected at approximately the same location during the two sampling periods.

SITE	REP	% FINES OCT, 1999	% FINES APR, 2000	RPD
SCFLT1	1	85.3	85.3	0 0%
SCFLT1	2	92.8	93.9	1.2%
SCFLT1	3	94.1	88.9	5.7%
SCFLT1	3D	52.4	87.1	49.7%
SCFLT1	4	80.7	64.4	22.5%
SCFLT1	5	86.4	89.0	2.9%
SCFLT2	1	94.1	93.1	1.1%
SCFLT2	2	90.1	89.3	0.9%
SCFLT2	3	67.9	55.5	20.1%
SCFLT2	3D	92.1	67.3	31.1%
SCFLT2	4	55.2	68.5	21.5%
SCFLT2	5	84.2	54.2	43.3%
SCFLT3	1	32.8	34.2	4.2%
SCFLT3	2	70.5	57.4	20.5%
SCFLT3	2D	58.7	67.3	13.7%
SCFLT3	3	65.9	49.1	29.2%
SCFLT3	4	81.1	85.6	5.4%
SCFLT3	5	42.2	48.5	13.9%
SCFLT4	1	22.0	16.8	26.6%
SCFLT4	2	61.6	14.7	122.8%
SCFLT4	3	63.8	61.8	3.1%
SCFLT4	4	49.6	45.2	9.2%
SCFLT4	4D	36.7	44.9	20.2%
SCFLT4	5	36.8	40.5	9.4%
SCTTS1	1	92.3	88.0	4.8%
SCTTS1	1D	82.9	86.3	4.0%
SCTTS1	2	93.7	93.7	0.1%
SCTTS1	3	88.2	84.0	4.8%
SCTTS1	4	93.5	91.1	2.6%
SCTTS1	5	94.4	45.1	70.8%
SCTTS1	6	89.6	74.4	18.5%
SCTTS1	6D	91.0	86.5	5.1%
SCTTS1	7	77.9	67.4	14.5%
SCTTS1	8	47.0	77.8	49.4%
SCTTS1	9	88.1	93.6	6.1%
SCTTS1	10	94.7	94.6	0.1%

Table 31. Comparison of sediment particle sizes (Continued)

A comparison of sediment particle size characteristics between sediments collected in October, 1999 and April, 2000 based on the percent fines, where fines are defined as the sum of the % silt and % clay. The relative percent difference (RPD), the absolute difference between the values divided by the mean, provides an estimate of the similarity of the samples collected at approximately the same location during the two sampling periods

SITE	REP	% FINES OCT, 1999	% FINES APR, 2000	RPD
CPSTL1	1	71.6	81.0	12.3%
CPSTL1	2	69.0	82.3	17.6%
CPSTL1	3	54.3	62.0	13.3%
CPSTL1	4	80.2	76.6	4.6%
CPSTL1	5	81.3	89.5	9.7%
CPSTL1	5D	85.0	81.6	4.1%
CPSTL1	6	79.8	91.9	14.2%
CPSTL1	6D	85.0	93.4	9.5%
CPSTL1	7	77.5	71.5	8.1%
CPSTL1	8	90.1	85.1	5.7%
CPSTL1	9	54.8	73.8	29.7%
CPSTL1	10	66.2	84.1	23.9%
CCR	1	97.1	97.4	0.3%
CCR	2	99.3	93.8	5.7%
CCR	3	95.2	96.6	1.5%
CCR	4	96.6	86.6	10.9%
CCR	5	96.8	92.7	4.3%
CCR	6	96.6	96.5	0.1%
CCR	7	97.7	95.1	2.8%
CCR	8	96.3	92.9	3.6%
CCR	9	96.4	90.0	6.8%
CCR	10	97.8	93.5	4.5%
WRC		96.3	91.3	5.3%

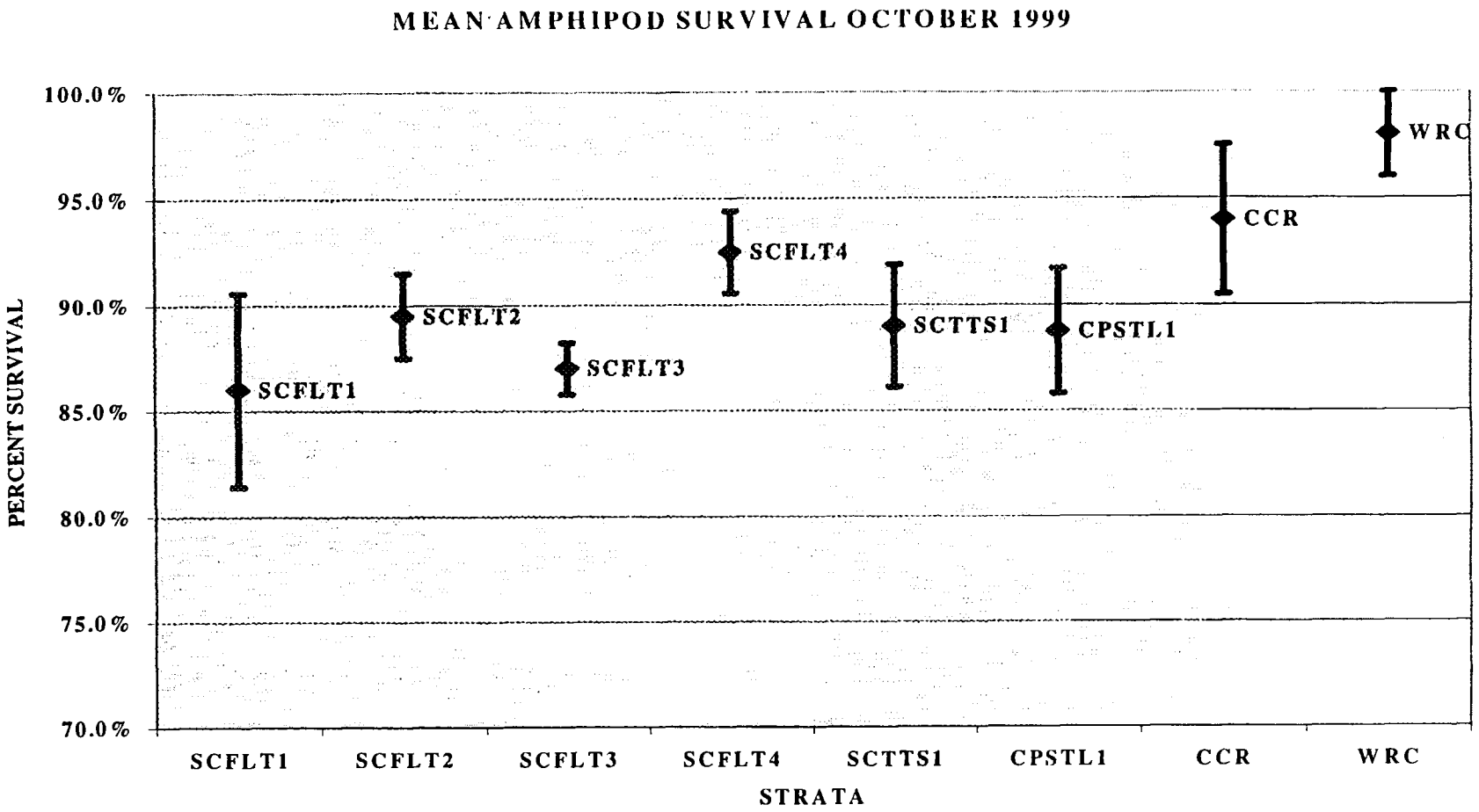

Figure 1. Mean survival and standard error for 10 day amphipod bioassay using sediment collected in October, 1999 from the Elizabeth River as well as reference (CCR) and control (WRC) sites. Since 20 organisms were used in each replicate, 1 organism represents a 5% change in this figure. SCFLT# = (1 = northeast strata, 2 = mid reach strata, 3 = northwest strata, and 4 = southwest strata) Scuffletown Creek, Southern Branch; SCCTS1 = Scotts Creek off the Mainstem; CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River; CCR = Carters Creek reference site, and WRC = Ware River control sediment. All samples were stratified random samples from within the study area including CCR, however, the Ware River control was one grab sample used to perform 5 replicate bioassays.

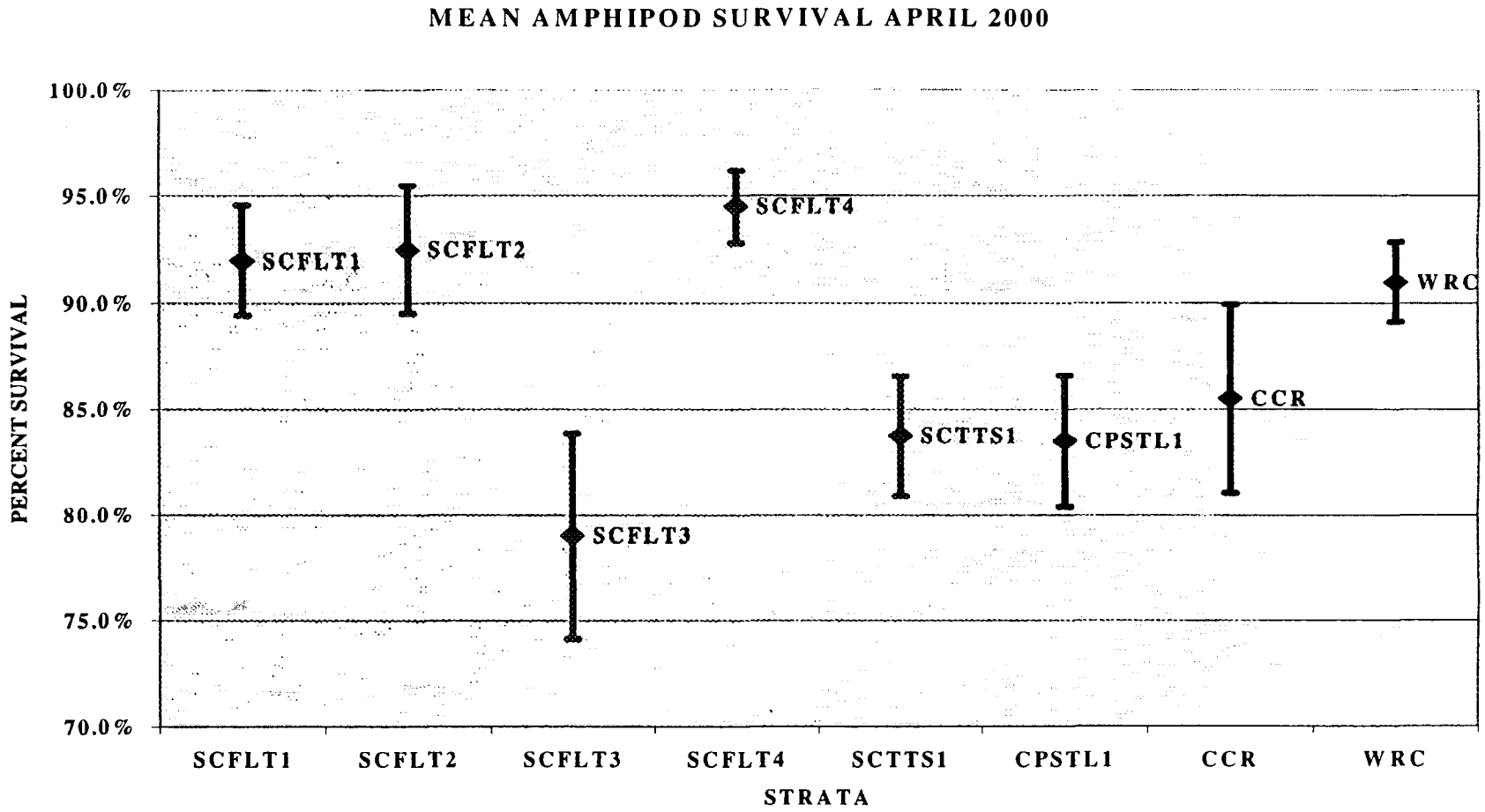

Figure 2. Mean survival and standard error for 10 day amphipod bioassay using sediment collected in April, 2000 from the Elizabeth River as well as reference (CCR) and control (WRC) sites. Since 20 organisms were used in each replicate, 1 organism represents a 5% change in this figure. SCFLT# = (1 = northeast strata, 2 = mid reach strata, 3 = northwest strata, and 4 = southwest strata) Scuffletown Creek, Southern Branch; SCCTS1 = Scotts Creek off the Mainstem; CPSTL1 = in the vicinity of Campostella Bridge, Eastern Branch, Elizabeth River; CCR = Carters Creek reference site, and WRC = Ware River control sediment. All samples were stratified random samples from within the study area including CCR, however, the Ware River control was one grab sample used to perform 5 replicate bioassays.

Seltzer, Craig L NAO02

From: ROBERT BURGESS [BURGESS.ROBERT@epamail.epa.gov]
Sent: Thursday, September 30, 1999 9:40 AM
To: Beth_McGee@fws.gov; Craig.L.Seltzer@NAO02.USACE.ARMY.MIL
Cc: BERRY.WALTER@epamail.epa.gov
Subject: Toxicity Data for Elizabeth River Sediments

Craig,

Attached is the Elizabeth River sediment toxicity data set. Below is a brief description of the test methods and results:
Attached are the results of the toxicity tests performed with the amphipod Ampelisca abdita on 20 sediments from the Elizabeth River. The tests were 10 days in duration and static and conducted in 20 g of sediment with 60 mL of aerated overlying water. The design consisted of three replicates per treatment. Two test series were performed with 10 sediments in each series.
As you can see, the responses of our controls were acceptable (i.e., 80% survival) while 19 of the 20 Elizabeth River sediments had survival less than 80%. In general, these sediments were very toxic.
Because ammonia is frequently suspected or associated with sediment toxicity, we measured overlying water ammonia on the last day of the tests (day 10). Generally, the levels of ammonia were not sufficiently high to suggest ammonia was causing all of the observed toxicity. Further, regression of total and unionized ammonia versus survival resulted in very weak relationships ($r^2 = 0.19$ and 0.12 for total and unionized ammonia, respectively). In aquatic systems, unionized ammonia is the chemical form of ammonia associated with toxicity. Although a thorough investigation of the causes of toxicity has not been performed for these sediments this analysis of the role of ammonia suggests it is not a significant contributor to the observed toxicity. Other toxicants appear to be active.
If you have any questions, please contact me.
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EPA Toxicity Tests

Table 1) Results of 10-day amphipod *Ampelisca abdita* static toxicity tests performed on sediments from the Elizabeth River area. Long Island Sound (LIS) sediment was used as a control sediment. Mean ± standard deviation.

Site	Survival (%)	Total Ammonia (mg/L)	Unionized Ammonia (mg/L)
LIS #1[a]	86.7 ± 15.3	0.25 ± 0.14	0.02 ± 0.01
LIS #2[a]	90 ± 10	0.15 ± 0.12	0.01 ± 0.01
SFF020 [c]	0 ± 0	14.0 ± 2.46	0.90 ± 0.14
SFF030	0 ± 0	0.07 ± 0.02	0 ± 0
SFF040[b]	0 ± 0	26.7 ± 3.88	0 ± 0
SFF050	53.3 ± 25.2	0.07 ± 0.01	0 ± 0
SFF060	23.3 ± 15.3	0.24 ± 0.10	0 ± 0
SFC010	36.7 ± 11.5	0.07 ± 0.01	0 ± 0
SFC020	63.3 ± 15.3	0.15 ± 0.04	0 ± 0
SFC030	40 ± 20	0.61 ± 0.13	0.01 ± 0
SFC040	80 ± 20	0.11 ± 0.01	0 ± 0
SFC050	26.7 ± 15.3	0.09 ± 0.02	0.01 ± 0.01
SFC057 [c]	0 ± 0	0.30 ± 0.04	0.01 ± 0
SFC064	6.67 ± 11.5	10.3 ± 1.31	0.31 ± 0.09
SFC070	3.33 ± 5.77	7.45 ± 1.51	0.23 ± 0.04
SFC073	20 ± 10	0.12 ± 0.05	0 ± 0
SFC090	0 ± 0	0.58 ± 0.37	0 ± 0
ERF011 [c]	13.3 ± 23.1	9.37 ± 0.78	0.38 ± 0.02
ERC001 [c]	20 ± 20	10.5 ± 0.59	0.14 ± 0.01
ERC004 [c]	0 ± 0	1.74 ± 1.46	0.04 ± 0.03
ERC005 [c]	43.3 ± 25.2	3.08 ± 0.70	0.07 ± 0.02
ERC008 [c]	0 ± 0	4.00 ± 1.61	0.14 ± 0.07

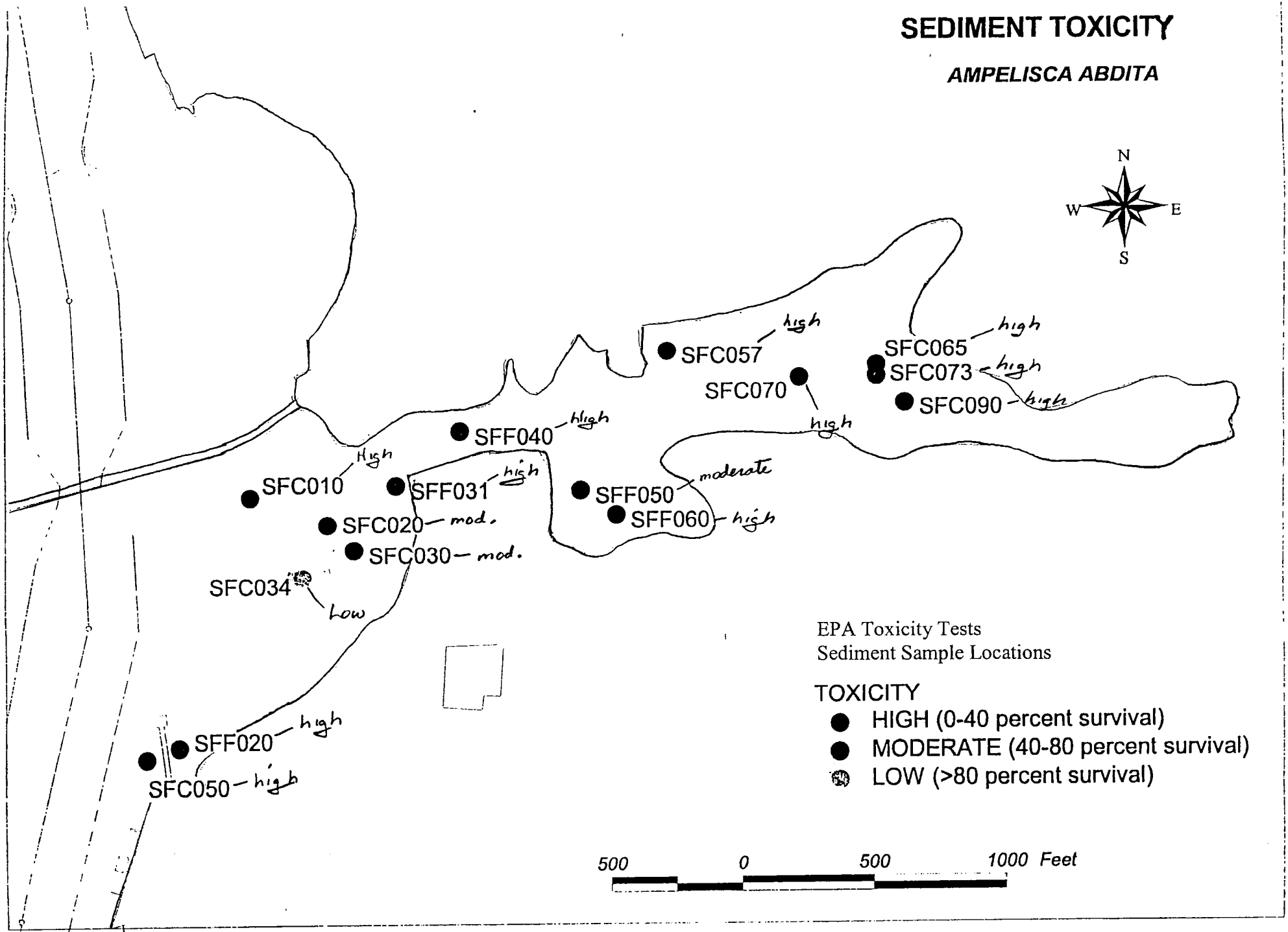
[a] Two test series were performed; LIS#1 and LIS#2 are the respective controls.

[b] Unusually low pH in overlying water.

[c] Oil observed during test breakdown.

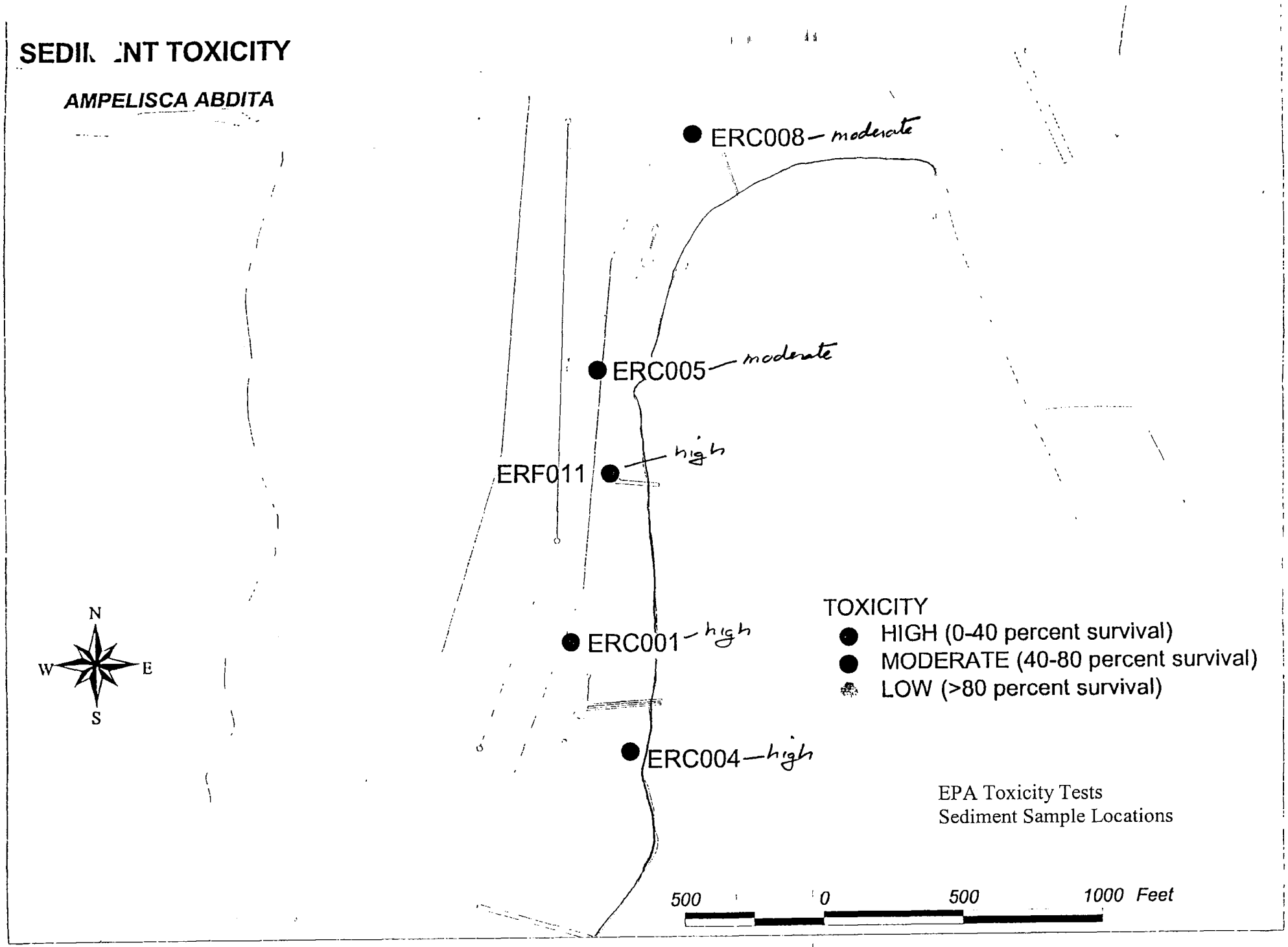
SEDIMENT TOXICITY

AMPELISCA ABDITA



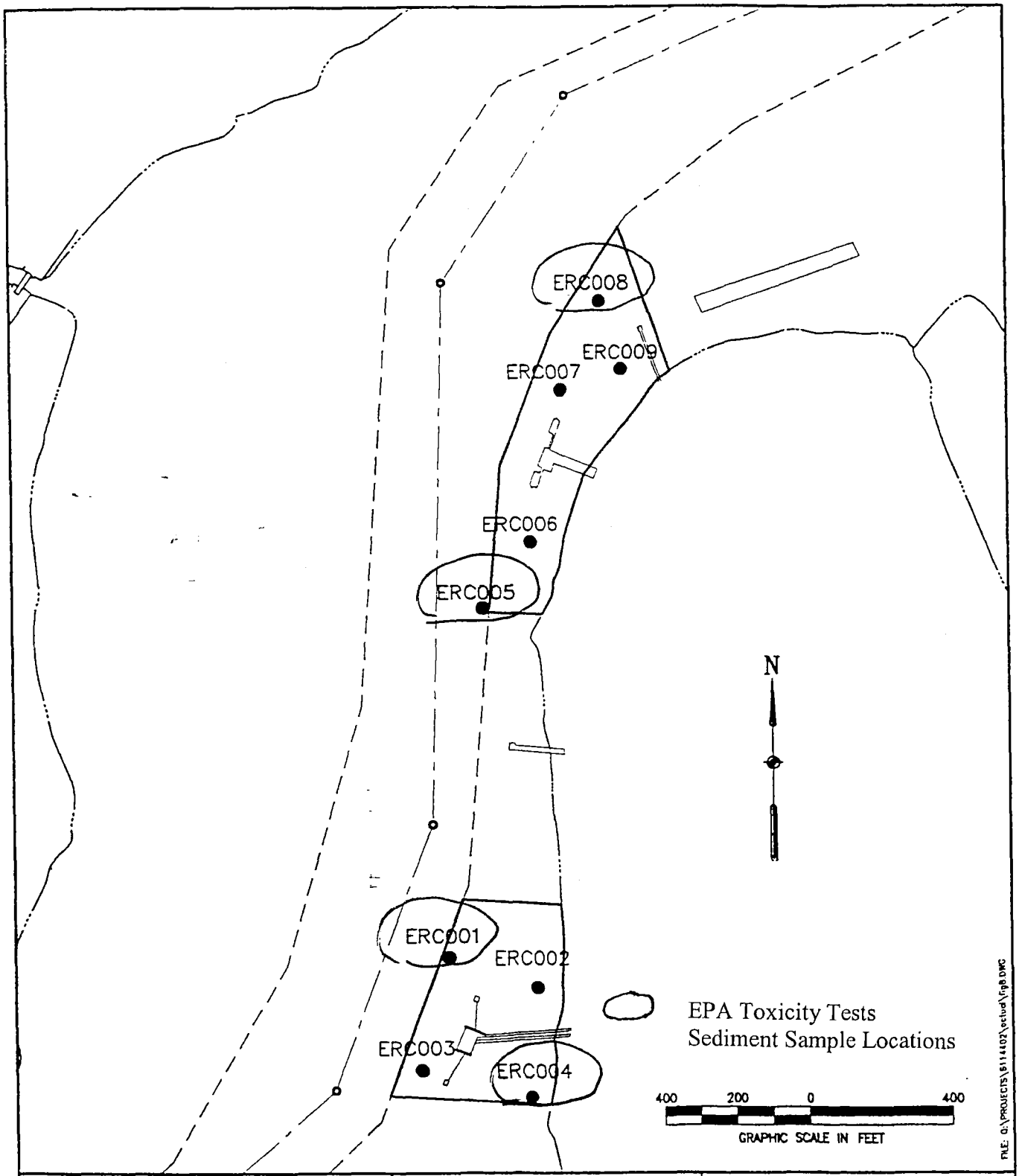
ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION

SCUFFLETOWN CREEK



ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION

EPPINGER & RUSSELL



EA ENGINEERING, SCIENCE, AND TECHNOLOGY

ELIZABETH RIVER PHASE I
SEDIMENT INVESTIGATION
NORFOLK, VIRGINIA

SAMPLING LOCATIONS AT EPPINGER & RUSSELL – COARSE GRID

PROJECT MGR	DESIGNED BY	DRAWN BY #	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
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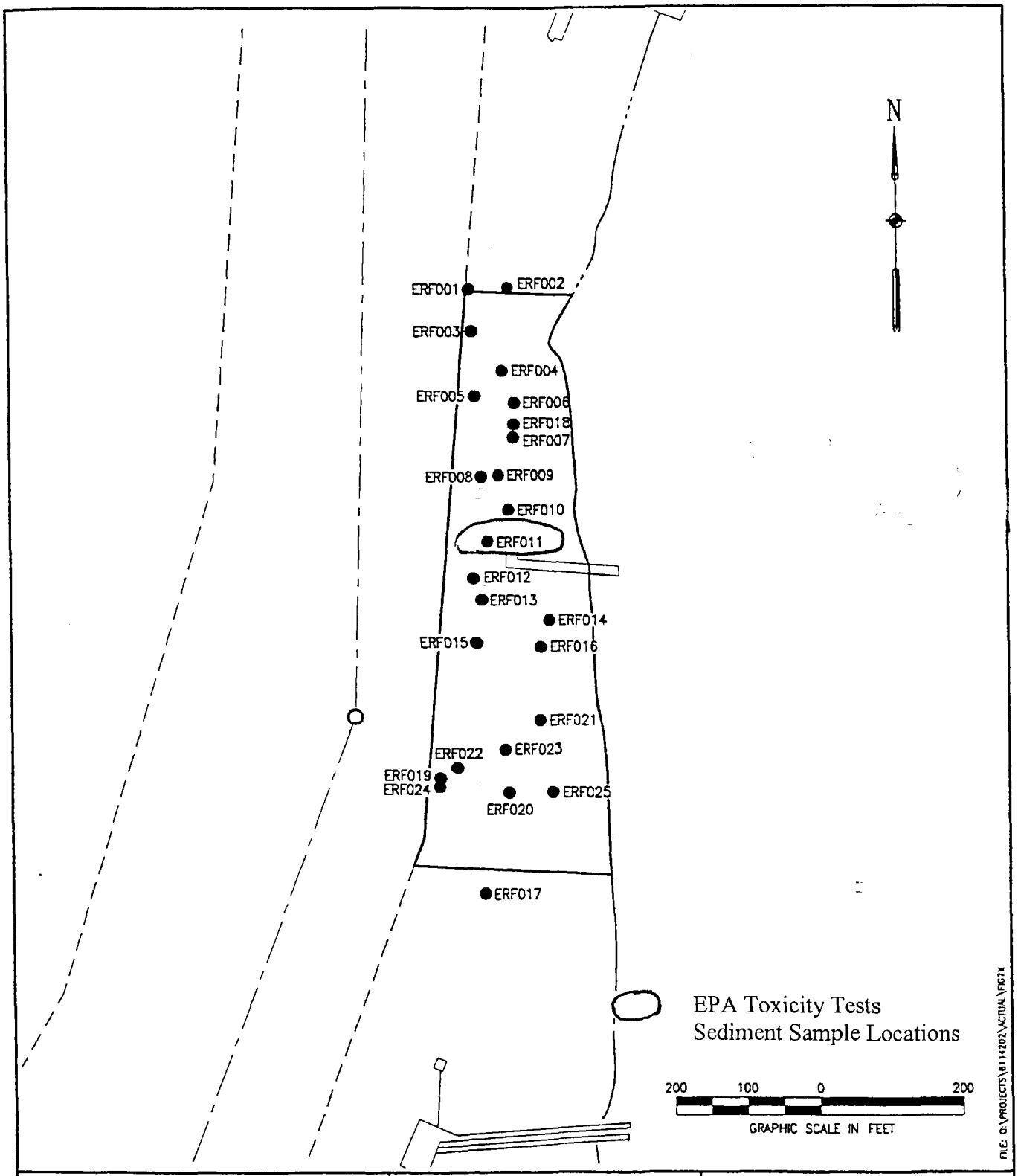

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	ELIZABETH RIVER PHASE I SEDIMENT INVESTIGATION NORFOLK, VIRGINIA	SAMPLING LOCATIONS AT EPPINGER & RUSSEL – FINE GRID

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
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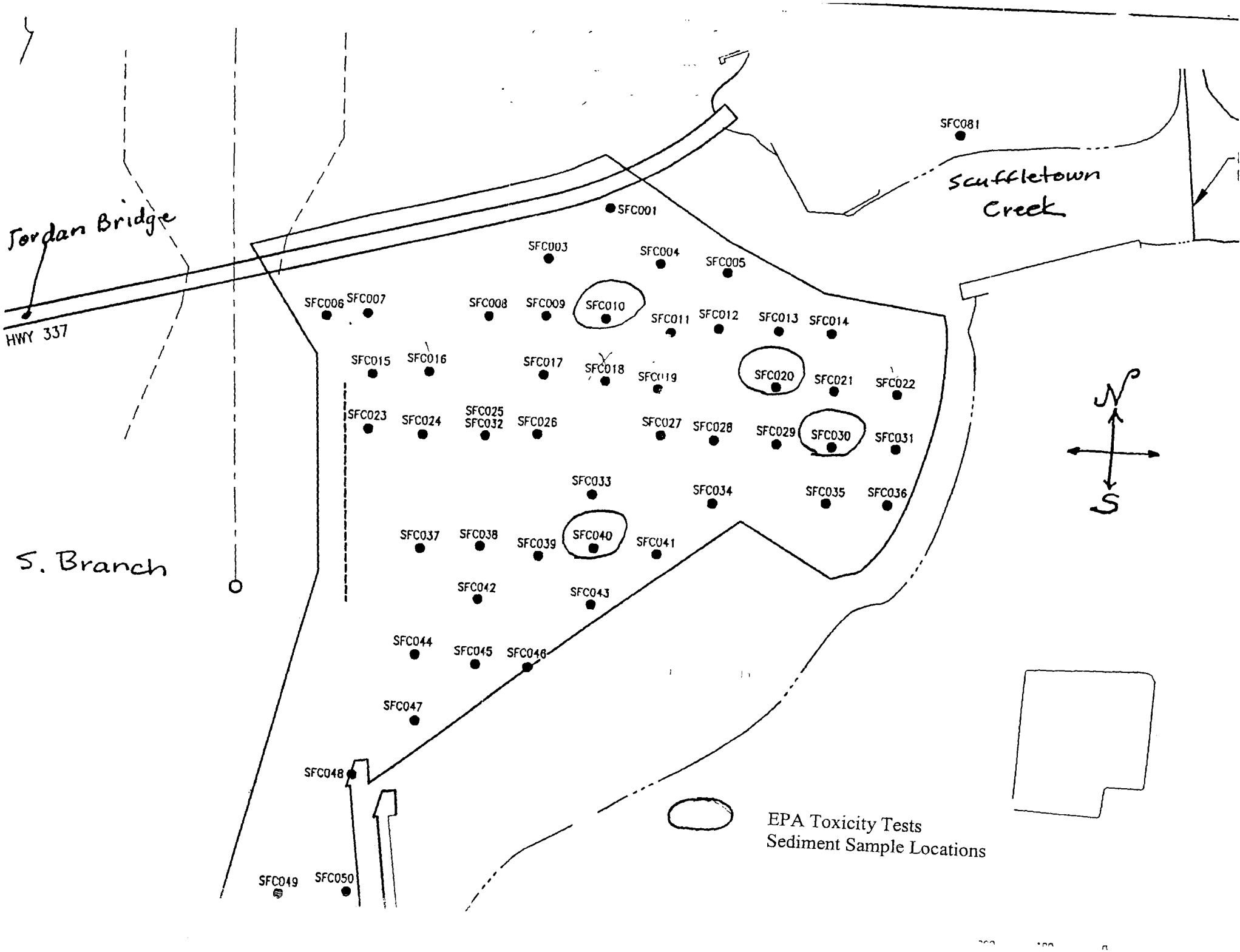
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S. Branch
Scuffletown Creek
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SFC003
SFC004
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SFC011
SFC012
SFC013
SFC014
SFC015
SFC016
SFC017
SFC018
SFC019
SFC020
SFC021
SFC022
SFC023
SFC024
SFC025
SFC032
SFC026
SFC027
SFC028
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SFC033
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SFC040
SFC041
SFC042
SFC043
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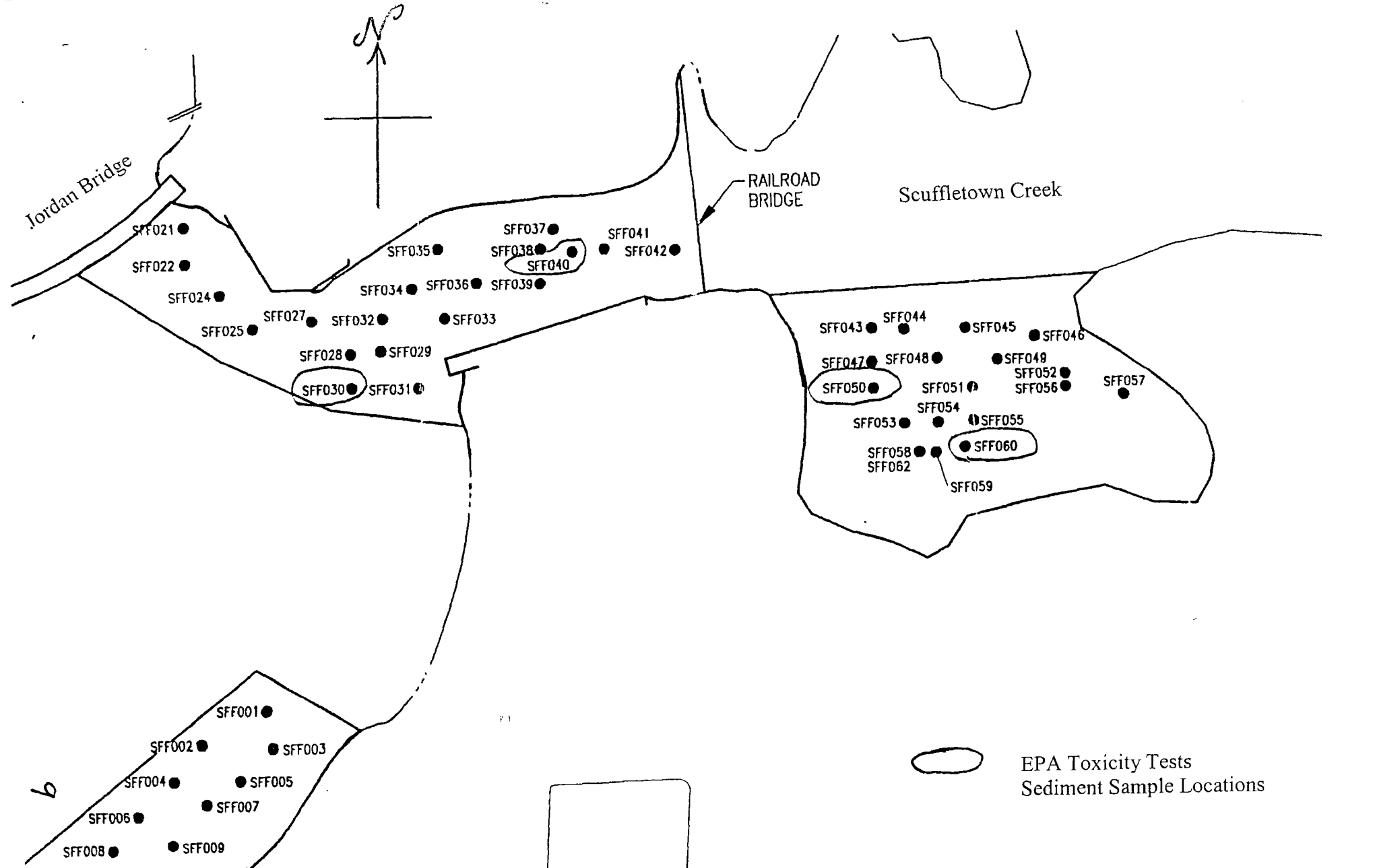
N
S
EPA Toxicity Tests
Sediment Sample Locations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RAILROAD BRIDGE
Scuffletown Creek
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SFF022
SFF024
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SFF036
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SFF059
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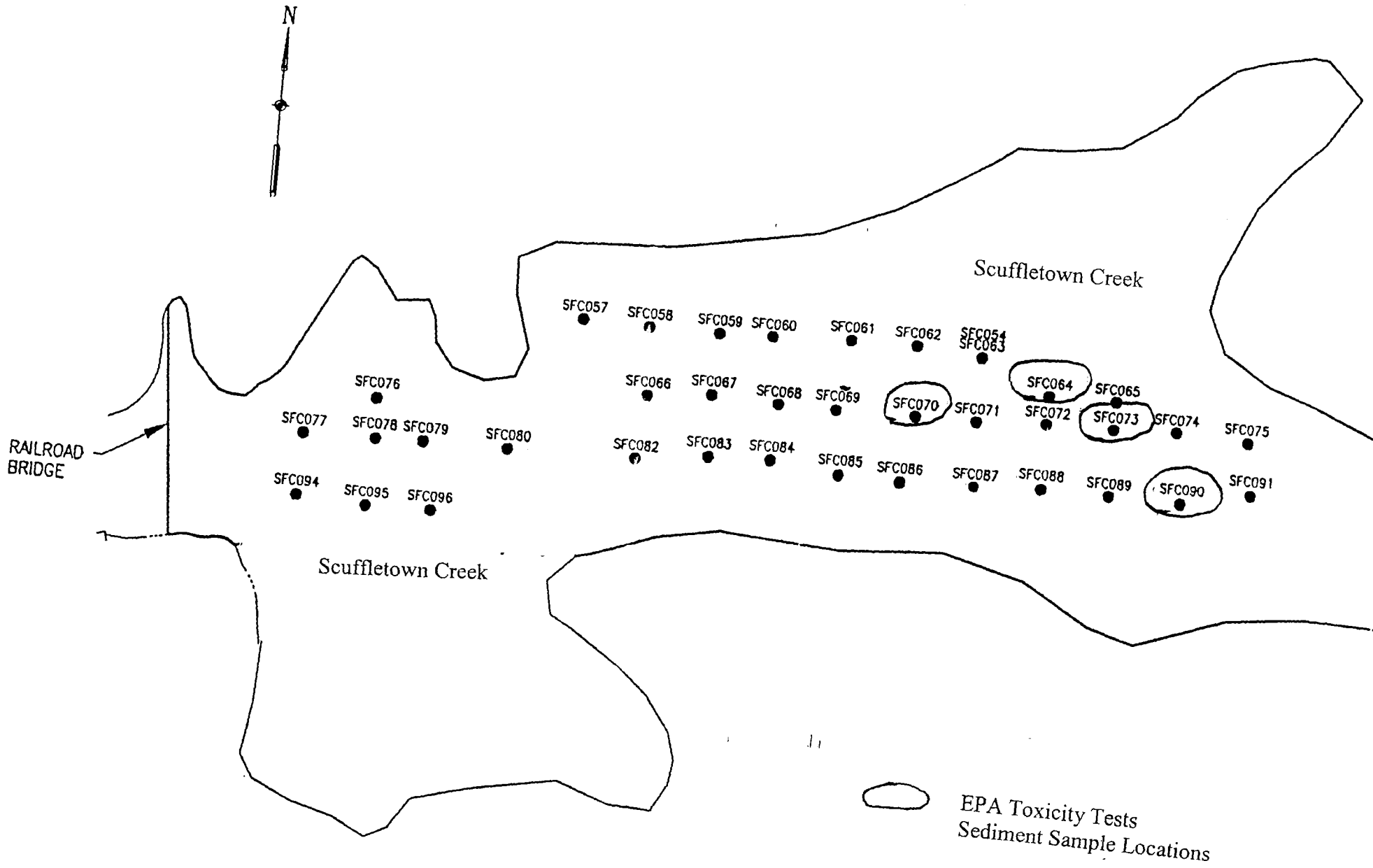
EPA Toxicity Tests
Sediment Sample Locations


N
Scuffletown Creek
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SFC094
SFC095
SFC096
RAILROAD BRIDGE
Scuffletown Creek
EPA Toxicity Tests
Sediment Sample Locations

01